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THE GEGENSCHEIN OR ZODIACAL COUNTERGLOW.

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EARLY HISTORY.

A long series of observations of the zodiacal light was made during Commodore Perry's expedition to Japan, by the Rev. George Jones, chaplain of the United States steam frigate Mississippi. This work, which consisted in drawing the outlines of the zodiacal light on star charts, was published by the government in 1856. It is a large quarto volume of 705 pages, containing 352 full page charts (including 11 by Cassini in 1685-1687).

Though Mr. Jones was assiduous in his observations of the zodiacal light, attested by his 341 full page plates, for some unaccountable reason he seemed to fail utterly in noticing the gegenschein (which was not then known) with the possible exception of one occasion, Aug. 5, 1853; his description on that date, however, is so vague that it is not certain he really saw the gegenschein even then. A letter of his on the subject in the *Astronomical Journal*—No. 84, for May 26, 1855,—which I do not have access to, called forth a letter from Alexander von Humboldt, (*A. N.* 989) in which Humboldt appears also to have seen something of the kind in 1803, and which he attributed to a reflection from the western zodiacal light. But from his account it seems doubtful if the observations really referred to the gegenschein.

Both Jones and Humboldt failed to follow up the subject sufficiently to show that there really was a faint light in the sky opposite the Sun.

The first definite observations of the gegenschein seem to have been made by Theodore J. C. A. Brorsen who gives a brief account (dated November 13, 1855,) of the gegenschein in *A. N.* 998, which perhaps was called forth by Humboldt's paper though Brorsen does not refer to it. In this account Brorsen states that he had seen the object during the two previous years. Though he recognized its position as being opposite the Sun, he gives no positions of it that would prove such a statement.

His account of the gegenschein is in part also somewhat vague.

He speaks of the phenomenon as being a Vernal and Autumnal gegenschein—that is, as being visible near the Vernal and Autumnal equinoxes. The closing sentence of his account is puzzling; he says "both gegenschein could be seen here, at the same season, on every clear evening." If he means that both gegenschein—the Vernal and the Autumnal—were visible on the same evening the statement becomes absurd.

Brorsen speaks of the September, October and November gegenschein as being much smaller and fainter than the one seen in March, April and May.

After this no attention seems to have been paid to the subject until in 1868 it was independently discovered by Mr. T. W. Backhouse, of Sunderland, England. In *M. N.* for November, 1875, Vol. 36, p. p. 46-48, Mr. Backhouse gives some comparisons of his, from 1871, of the gegenschein and the point exactly opposite the Sun, from which he showed that the object was essentially on the ecliptic, and somewhere near 180° greater in longitude than the Sun, though he gives no observations of position.

In 1883 so little was known or written about this object, that I had never heard of its existence. One night in the first of October in that year while comet seeking at the Vanderbilt University, Nashville, Tennessee, my attention was attracted by what appeared to be a spot of local haze south-east of the square of Pegasus. Noticing this same appearance the next night, I watched it and soon found that it was not a spot of haze, but that it remained constant all night, and a few nights observations convinced me that it was a real object belonging to the sky and that it was moving eastward about one degree a day. Upon finding out its character I secured some positions of it and sent them to an eminent astronomer, asking for information about it. The answer was that I had found the gegenschein, and I was directed where to find information on the subject. Since then I have paid much attention to this object and have found out several things previously unknown about it.

Previous to my observation it had been found that the gegenschein maintained a position opposite the Sun, from which peculiarity it received its name. The few observations of it also seemed to show that it did not always apparently lie in the ecliptic, but was usually a little north of that plane.

Changes in the Form of the Gegenschein.

I have watched the gegenschein for over fifteen years and have

therefore become pretty familiar with its appearance in the various parts of the sky in which it can be seen. I have found that it undergoes singular changes in form and that these changes are periodic with the seasons,—that is, they repeat themselves in the same parts of the sky. There are two points in its path where the gegenschein can not be seen. These are when it is crossing the Milky Way in the months of December and June.

I will briefly state its form as seen during the different months.

In January it seems to be small and somewhat elongated.

In February it is, in general, very large and round.

In March it is round and large—especially so in the latter part of the month.

In April it is large and a little elongated.

I have not sufficient observations in May to tell anything about its form.

In June it is invisible.

Towards the end of July it becomes visible and is small and somewhat extended.

At least during the latter part of August, it is large and round.

Throughout the month of September it is large and round and very distinct—its diameter being as much as 20°.

About the first of October it is essentially round and large, but it soon undergoes a striking change. By the 4th or 5th of the month it is slightly elongated. From about the 10th or 11th it becomes very much elongated along the ecliptic, and especially so about the 18th, when it seems to be a mere swelling on a zodiacal band stretching a great distance along the ecliptic.

For the first five or six days of November it continues to be elongated, but after the 10th it seems to become more roundish.

In December it is invisible.

Its Connection with Zodiacal Bands.

Much of the time the gegenschein is intimately connected with a zodiacal band—which is sometimes seen running from it eastward or westward as the case may be, and at times both to the east and to the west. On some occasions this zodiacal band has been seen to stretch across the sky at midnight from the gegenschein, connecting the evening and morning zodiacal lights. This zodiacal band is about 3° or 4° in width and is best seen where it passes between the Pleiades and Hyades in the morning skies.

But the zodiacal band is not always present. There is perhaps no distinct zodiacal band in August. The same can be said with respect to September, but a band is present in October and No-

vember. There seems to be no noticeable band in March. A faint one was several times recorded in April, and in May there seems to be a distinct zodiacal band across the sky along the ecliptic and connected with the gegenschein.

Its Position with Reference to the Sun.

As I have said, the earlier observations seemed to show that the gegenschein always had a small north latitude, and that it was approximately 180° ahead of the sun in longitude. My observations of its position verify the slight north deviation from the ecliptic, and show also that it lags in longitude, that is, it is not quite 180° ahead of the sun.

These two facts are evident from the following:

Position of the Gegenschein with Reference to the Sun and the Ecliptic.

	Latitude.	$\lambda - \odot$	
	°	°	
1883 to 1887	+ 0.4	179.4	16 observations.
1888 to 1891	+ 1.3	179.4	16 "
1893	+ 0.5	179.6	22 "
1894 to 1899	+ 0.3	179.8	17 "
	+ 0.62	179.55	

I believe these values should be 0°.00 and 180°.00 respectively. The observations were always made south of the zenith and in most cases to the east of the meridian. Atmospheric absorption would therefore have a tendency to throw the center of brightness north of the ecliptic and backwards in longitude, as is shown to be the case by the observations.

Some Attempts to Explain the Gegenschein.

My observations seem to negative any inclination of the path of the gegenschein to the ecliptic. It doubtless lies exactly in the ecliptic and always exactly opposite the sun. This of itself is suggestive of its being a phenomenon due in some way to the earth alone. The fact that the gegenschein is seen perhaps better on a not too pure sky is also suggestive of its non-existence as a celestial body in the ordinary sense of the word. To me it has always appeared to be an atmospheric phenomenon, but there are several objections to this explanation, the main one being the absence of any sensible parallax. If it were refracted sunlight reflected from opaque particles in the atmosphere there would of course be an enormous parallax. This explanation therefore seems improbable, yet I cannot feel satisfied that the gegenschein is not in some way connected with our own atmosphere.

No satisfactory theory has yet been offered to explain the gegenschein, though one connecting it with the asteroidal zone has received some consideration and apparently has much in its favor, but there are objections to the theory which cannot easily be reconciled with the observed facts.

For a popular exposition of this theory I will quote from a previous article of mine on the subject:

"Between the orbits of Mars and Jupiter are known to be no less than four hundred small planetary bodies. It is probable there are thousands and possibly millions more of these dust worlds. The smaller ones found in recent years are perhaps not over 10 or 15 miles in diameter. As they decrease in size doubtless they multiply in number until finally they exist in untold multitudes of a size comparable with small stones and particles of dust, which no telescope will show individually. Each one of these small bodies is a miniature planet and must shine as a planet by reflecting the light of the Sun. It therefore must present to us phases just as Mars does, but from the smallness of the objects we cannot see these phases—but none the less they must have an effect on the brightness of each little asteroid, and must diminish its light accordingly.

Let us assume there are a sufficient number of these tiny planets. Though they may be too small to be seen individually in a telescope, their combined light may be so great as to affect the eye and thus we might expect to see a feeble zone of light extending across the sky and corresponding to the asteroidal zone. Such we actually have in the zodiacal band. What would be the effect of phase of these individually small bodies upon the appearance of this zone of light? When opposite the Sun each of the objects would shine with full enlightened disc, and this vast collection of fully illuminated particles would augment the light of the zone and give a greater luminosity immediately opposite the Sun. Away from opposition and the phase would begin to diminish the quantity of illumination. To this must also be added the fact that at opposition each asteroid would be nearer us and brighter from this cause also. Both causes would tend to give a maximum of light opposite the Sun—a gegenschein."

This theory I believe is due to Professor Arthur Searle of Harvard College Observatory.

In the *Observatory* for January, 1899, Mr. J. Evershed offers an explanation of the gegenschein, which assumes it to be a tail to the earth, produced by the escape of molecules of hydrogen and helium away from the earth in a direction opposite the Sun in

a similar manner to the formation of a comet's tail. The absence of any parallax is fatal to this theory.

I have often noticed late in the afternoon when my back was towards the Sun, a brightish glow on the dry grass about the shadow of my head, due to the rapid increase of shadow effect away from the point directly opposite the Sun. Near the shadow of the head the shadows of the grass, etc., would be hidden by the grass itself, and that region would appear brighter than at a slightly greater distance, where the shadows would become exposed and hence produce a lessening of brightness away from the shadow of the head, the bright spot about the head is therefore a gegenschein, and this ought to be suggestive of an explanation of the real gegenschein.

Suggestion for Observing the Gegenschein.

There seems to be an impression general among astronomers that the gegenschein is a faint and difficult object, and that it requires the keenest eyesight to see it. Perhaps it is for this reason that so few observers have seen it. This however is a false idea, for there are really very few things in the sky that are easier to see than the gegenschein. Indeed it seems hardly possible that anyone paying a casual attention to the face of the heavens could fail to discover it for himself.

I have never yet tried to show this object to anyone that it has not been seen readily. Since being at this observatory I have pointed it out to at least ten persons, none of whom had ever seen it, though some of them had carefully looked for it previously. I do not think any one of these persons would now have any trouble in picking up the gegenschein if the conditions were at all favorable.

In October, 1897, during the Congress of astronomers at the Yerkes Observatory, I pointed the gegenschein out to Professor Newcomb who had never seen it with certainty. He saw it with no difficulty and located it. Our independent locations of position agreed closely and placed its center within a degree of exact opposition to the Sun. Professor Newcomb's remark: "I thought you described it as being round, this object is elongated," showed that he saw it well, for it was then in the position in which it always appears elongated.

In its most conspicuous condition the gegenschein is large and round, and from 15° to 20° in diameter, and very feebly brighter in the middle. Its appearance is not that of nebulous matter. It looks more like a spot of slightly luminous haze.

Like all objects of its class, it is considerably better seen by averted vision. The best way to see it is to turn the face, not towards it, but say to the right, to a point some 60° or 70° distant from it, then by turning the eyes alone in its direction the gegenschein will come out with surprising distinctness, as a large hazy light, covering a considerable area of the sky. The advantage of this method of observation is, I assume, due to the fact that the light then enters the eye obliquely and falls to one side on an unused and therefore more sensitive portion of the retina. If looked at direct the light then falls on that part of the retina immediately behind the pupil, which, by constant use, is more or less dulled. Squinting the eye, for some reason, also aids in seeing the gegenschein.

When well seen, the gegenschein does not seem to be extremely far away, indeed it always appears to me to be an illumination of our own atmosphere and not a distinct celestial body.

There are many amateur observers at the present time who are ready to take up any kind of observing work that will be valuable to the science of astronomy and creditable to themselves, and which does not require powerful instruments. To these I would say that no field of work within their reach offers more chance for valuable results than careful observations of the gegenschein. After one gets familiar with this object there is no difficulty in getting good positions of it. Especially valuable will be careful descriptions of its form at the various points in its path. Its connection with the zodiacal band is an important subject for observation.

Several suggestions have been offered as to the best method for determining its position. Experience teaches me that the best way is to study it carefully until sure of the center of figure, then locate this with reference to the nearest fixed star or stars. It will frequently be found that a faint naked eye star is near its center. Such a star, if properly identified, serves best for the determination of position because its brightness does not interfere with the observations, and also because such a star is more frequently seen near the center of the gegenschein—for there are more of them. The observer, if familiar with the value of a degree, can readily estimate the relative position of star and gegenschein with considerable accuracy.

As he becomes more familiar with the work, the observer will feel that it is a poor observation that places the center of the gegenschien much more than a degree from exact opposition to the Sun. I would however warn him against reducing the ob-

servations before he is through with the series. It is well enough to do this reduction when the moon prevents observations for the time being, otherwise he may be influenced by his knowledge of the deviation of a previous observation, when he makes another within a day or two of the first.

How closely one can observe this object with the naked eye—the only means at present available—may be formed from the following tabulation of probable errors from my observations, which now extend through nearly sixteen years.

PROBABLE ERRORS OF GEGENSCHEIN OBSERVATIONS.

	In Latitude.		In Longitude	
	one obs'n.	mean	one obs'n.	mean
	°	°	°	°
1883 to 1887	± 1.5	± 0.38	± 1.4	± 0.34
1888 to 1891	± 1.3	± 0.30	± 1.4	± 0.34
1893	± 0.3	± 0.06	± 0.7	± 0.14
1894 to 1897	± 0.6	± 0.17	± 0.9	± 0.28

As will be seen there is a decided improvement in the later observations, doubtless due to the observer becoming more skilled in the work. The observations of 1893 appear to be specially good; the utmost care was taken in these as they were made for comparison with a similar set to be obtained at Arequipa, Peru, under the direction of Professor E. C. Pickering.

THE ABSENCE OF ANY LARGE PARALLAX.

The solution of several questions was involved in the observations of 1893. It was the first time that simultaneous observations were made of the gegenschein from the northern and southern hemispheres. The question of parallax was one of these considerations. No appreciable parallax was revealed by the work. Had the gegenschein been an actual object at a distance not greater than the moon the observations would doubtless have indicated its parallax; and if at no greater distance than half that of the moon, the parallax would have been easily determined.

IT DOES NOT SEEM TO REQUIRE THE PUREST ATMOSPHERE FOR ITS OBSERVATION.

There seems to be an impression that the gegenschein can be seen only under the very best atmospheric conditions—that is with an extremely pure sky. In reality there are hardly any atmospheric conditions that militate against its visibility, except a sky illuminated by a bright moon or the proximity of electric arc lights.

Indeed, throughout my observations, I have been struck with

the fact that a sky not over transparent is just as good (I won't say better) for observing the gegenschein as the clearest, darkest night. It therefore does not require the serene purity of a mountain atmosphere to see it well. I have even seen it in feeble moon light.

Above all, the observer must not look for an exceedingly faint and difficult object—one attainable only with the keenest eye sight. I believe it is for this latter reason that a good many people have looked squarely at it and failed to see it, because they thought it was a difficult object.

Averted or oblique vision, it must be remembered, is essential to see it well. The presence of bright stars often interfere very much, but mainly in the accurate location of its center.

Probable Photographs of the Gegenschein.

In Popular Astronomy for February, 1899, Dr. H. C. Wilson in speaking of some long exposure photographs he obtained of the Pleiades in the past fall and winter finds on the plates south of the Pleiades, some appearances that would suggest that he had secured photographic evidences of the gegenschein. This is not at all improbable for the gegenschein is bright enough to photograph readily, but the trouble in general would be that from its great size the object would not show for want of a large enough field to give contrast. I think that there would be no trouble at all in photographing it with a quick acting lens with a flat field of 30° or 40° diameter.

Observations of the Position of the Gegenschein.

For completeness, I have collected here all my observations of position of the gegenschein. These have been arranged symmetrically, and to them are added some eight or ten positions not heretofore printed.

My previous papers on this subject will be found in the *Astronomical Journal*: Vol. VII. (No. 168): Vol. XI, (No. 243): Vol. XIII, (No. 308) and Vol. XVII, (No. 403).

Position Observations of the Gegenschein.

Date.		d	h	m	α h	α m	δ °	λ °	β °	$\lambda - \odot$ °	Δ °
1883	Oct.	8	11	47	0	56	+ 6.6	15.5	+ 0.6	179.9	+ 0.1
		20	8	53	1	45	+ 10.7	28.2	− 0.1	180.8	− 0.8
		29	8	53	2	11	+ 15.5	35.8	+ 2.2	179.4	+ 0.6
	Nov.	18	7	41	3	37	+ 18.7	56.2	− 0.6	179.8	+ 0.2
		23	10	48	3	56	+ 18.0	60.7	− 2.3	179.1	+ 0.9
1884	Oct.	12	11	17	1	9	+ 7.5	18.7	+ 0.1	178.4	+ 1.6
	Nov.	10	9	50	3	11	+ 23.4	51.8	+ 5.3	182.5	− 2.5
1885	Feb.	6	10	19	9	9	+ 17.5	134.4	− 1.0	175.8	+ 4.2
	Mar.	19	11	46	12	6	+ 2.5	180.5	+ 2.8	180.7	− 0.7
	Oct.	3	11	46	0	41	+ 4.0	11.1	− 0.4	179.9	+ 0.1

	Date.	d	h	m	α h	m	δ °	λ °	β °	$\lambda - \odot$ °	Δ °
		15	12	14	1	15	+ 11.5	21.9	+ 3.2	178.8	+ 1.2
1886	Sept.	23	11	46	0	6	+ 2.6	2.4	+ 1.8	181.3	− 1.3
		28	9	50	0	24	+ 3.0	6.6	+ 0.6	180.7	− 0.7
	Oct.	1	11	17	0	28	+ 2.0	7.1	− 0.9	178.1	+ 1.9
1887	Mar.	14	10	19	11	26	+ 6.4	169.7	− 2.5	175.4	+ 4.6
		16	11	46	11	43	+ 3.9	174.6	− 2.0	178.3	+ 1.7
1888	April	4	11	55	13	0	− 3.4	195.1	+ 2.8	179.2	− 0.8
	Aug.	28	10	0	22	33	− 8.2	336.8	+ 0.8	180.4	+ 0.4
	Sept.	1	11	55	22	47	− 6.2	340.8	+ 1.6	180.5	+ 0.5
	Oct.	30	10	58	2	14	+ 13.5	35.7	+ 0.1	177.5	− 2.5
	Nov.	2	9	2	2	11	+ 17.4	36.4	+ 3.9	175.2	− 4.8
1889	Jan.	23	8	5	8	26	+ 20.4	123.9	+ 1.1	179.5	− 0.5
		27	11	12	8	46	+ 19.4	128.7	+ 2.1	180.1	+ 0.1
	Feb.	7	10	14	9	36	+ 17.0	140.7	+ 2.5	180.9	+ 0.9
		25	10	58	10	17	+ 13.5	155.4	+ 2.2	177.3	− 2.7
	April	29	11	55	14	29	− 14.6	219.6	+ 0.1	179.4	− 0.6
	July	21	11	12	20	11	− 19.5	300.7	+ 0.6	181.0	+ 1.0
	Oct.	23	11	55	1	53	+ 11.9	30.5	+ 0.2	179.3	− 0.7
1890	Mar.	11	9	46	11	29	+ 3.7	171.4	− 0.3	179.8	− 0.2
1891	April	3	10	29	12	48	− 1.8	198.1	− 0.3	183.8	+ 3.8
		30	9	17	14	25	− 12.3	218.0	+ 2.0	177.4	− 2.6
	May	2	10	0	14	40	− 13.4	221.9	+ 2.1	179.3	− 0.7
	July	31	11	30	20	43	− 18.4	308.3	− 0.2	179.7	− 0.3
	Sept.	28	13	0	0	20	+ 1.3	5.1	− 0.7	179.1	− 0.9
1893	Aug.	31	8	24	22	45	− 8.2	339.6	− 0.2	180.7	+ 0.7
	Sept.	1	8	54	22	47	− 8.2	340.1	+ 0.4	181.9	+ 1.9
		2	9	14	22	47	− 7.2	340.5	− 0.6	179.5	− 0.5
		3	10	8	22	53	− 6.9	341.9	+ 0.2	180.0	0.0
		8	11	4	23	1	− 3.6	345.2	+ 2.9	178.5	− 1.5
		9	11	14	23	9	− 4.6	346.5	+ 0.7	178.7	− 1.3
		9	13	54	23	21	− 3.8	349.5	+ 0.3	181.6	+ 1.6
		13	10	24	23	25	− 3.1	350.8	+ 0.6	179.1	− 0.9
		13	12	27	23	26	− 3.4	350.8	+ 0.2	179.1	− 0.9
		15	10	9	23	35	− 2.7	353.2	0.0	179.6	− 0.4
		16	11	15	23	33	− 1.5	353.2	+ 1.3	178.6	− 1.4
		18	11	54	23	49	− 0.5	357.3	+ 0.6	180.7	+ 0.7
		20	14	9	23	55	+ 1.3	358.4	+ 0.6	179.7	− 0.3
	Oct.	1	9	33	0	30	+ 3.5	8.3	+ 0.2	179.1	− 0.9
		3	9	53	0	41	+ 3.3	10.7	− 1.0	179.5	− 0.5
		4	11	48	0	43	+ 4.8	11.8	+ 0.2	179.5	− 0.5
		6	10	12	0	49	+ 6.0	13.6	+ 1.3	179.3	− 0.7
		7	10	53	0	57	+ 5.8	15.4	− 0.3	180.1	+ 0.1
		9	9	18	0	57	+ 7.3	16.6	+ 0.8	179.5	− 0.5
		11	12	23	1	8	+ 8.0	18.7	+ 0.7	179.5	− 0.5
		16	12	28	1	24	+ 10.8	23.4	+ 1.8	179.3	− 0.7
		18	12	23	1	29	+ 10.8	24.5	+ 1.4	178.3	− 1.7
1894	Aug.	27	12	55	22	36	− 8.9	337.2	0.0	182.2	+ 2.2
		30	11	15	22	40	− 7.9	338.5	+ 0.5	180.7	+ 0.7
	Sept.	4	11	0	22	56	− 6.9	342.5	0.0	180.8	+ 0.8
1895	Feb	27	13	30	10	41	+ 13.0	156.6	+ 0.4	177.0	− 3.0
	Mar.	23	12	30	12	15	− 0.1	183.5	+ 1.5	180.5	+ 0.5
	Sept.	18	10	30	23	43	− 0.6	355.8	+ 1.2	179.8	− 0.2
1897	Mar.	24	9	50	12	15	− 2.7	184.4	− 1.0	179.6	− 0.4
		26	12	30	12	24	− 2.9	186.8	− 0.3	179.9	− 0.1
	April	25	10	10	14	16	− 12.4	215.9	+ 1.0	179.7	− 0.3
		26	10	55	14	14	− 12.9	215.4	+ 0.7	178.2	− 1.8
		30	10	0	14	37	− 15.4	221.7	0.0	180.7	+ 0.7
	Sept.	20	11	50	23	56	+ 0.4	359.0	0.0	180.5	+ 0.5
	Oct.	18	9	0	1	32	+ 9.6	24.8	0.0	178.8	− 1.2
	Nov	19	11	10	3	36	+ 19.4	56.4	0.0	178.2	− 1.8
1898	Sept.	18	11	0	23	46	− 2.4	355.8	− 0.8	179.6	− 0.4
	Oct.	5	9	0	0	45	+ 4.8	12.2	0.0	179.3	− 0.7
1899	Feb.	10	10	0	9	33	+ 14.0	141.1	− 0.4	178.9	− 1.1

In this table α and δ are the right ascension and declination; λ and β are the computed longitude and latitude; $\lambda - \odot$ is the longitude of the gegenschein minus the longitude of the Sun and Δ is the deviation of this quantity (greater or less) from 180°.

The observations from 1883 to 1887 and from 1897 to 1899 are six hours slow of Greenwich, the other times are eight hours slow of Greenwich Mean Time.

ADDITIONAL DESCRIPTIONS OF THE GEGENSCHEIN.

The following descriptions of the gegenschein have not been published before.

1891, July 31. The gegenschein is 8° or 10° diameter. It is large, hazy and roundish.

1891, Sept. 28. Very diffused, 15° in diameter. There are faint zodiacal extensions to the east and to the west.

1887, Sept. 20. Large and very diffused. Roundish and 20° in diameter. A narrow zodiacal band runs beyond the Pleiades to the east and also to the west of the gegenschein.

1897, Oct. 18. It is very elongated and especially extends to the east.

1897, Oct. 24. It is strong, and very much elongated with diffused zodiacal band running both east and west from it. The center is brighter and very marked south of α and β Arietus.

1897, Oct. 25. It is very marked tonight. It is very elongated and extends as a broad diffused zodiacal band many degrees east and west.

1897, Oct. 29. Distinct and elliptical, and extends along the ecliptic for some 25° and is about 10° or 15° wide. This description would cover its appearance last night also.

1897, Nov. 19. It is very noticeable just south of the Pleiades It is 15° or 20° in diameter. Roundish and involves the Pleiades and can be seen above and beyond those stars.

1898, Sept. 18. Large and round; fully 20° in diameter. At midnight there is a faint zodiacal band running from it to the east, between the Pleiades and Hyades.

1898, Oct. 5. Slightly extended along the ecliptic. Large and dense and from 12° to 15° in diameter.

1899, Feb. 10. It is large, round and hazy. Some 20° in diameter and very noticeable close to the west of the "Sickle" of Leo. (See the enclosed sketch.)

YERKES OBSERVATORY, William's Bay, Wis.
1899, Feb. 22.

SPHERES OF ACTIVITY OF THE PLANETS.

ASAPH HALL.

FOR POPULAR ASTRONOMY.

The discovery by Professor William H. Pickering of a faint satellite of Saturn at a great distance from the planet recalls a small computation made some time ago, and which may now be of a little interest.

When the 26 inch equatorial of the Naval Observatory was mounted in 1873 Professors Newcomb and Holden made a careful search for new satellites of Uranus and Neptune. At that time it occurred to me to calculate the radii of the spheres of activity of these planets, and afterward I computed their radii for Venus and Mars. This sphere is defined by Laplace as the space within which the attraction of the planet is greater than that of the Sun. It is evident that this space is not exactly a sphere, but the assumption of Laplace is sufficient to give a good idea of the limit required. Take the usual astronomical units, or the mass of the Sun for unit of mass, and its distance from the earth as the unit of distance. The action of the Sun on a body will be $\frac{1}{r^2}$, r being the distance of the body. If m' be the mass of the planet, and r' its distance from the Sun, the action of the planet on the body will be $\frac{m'}{(r'-r)^2}$. The difference of the attractions of the Sun on the body and on the planet is

$$\frac{1}{r^2} - \frac{1}{r'^2} = \frac{r'^2 - r^2}{r'\ r^2} = \frac{(r'-r)(r'+r)}{r^2 r'^2} = \frac{2(r'-r)}{r^3}; \text{ nearly.}$$

We shall satisfy the condition if we make

$$\frac{1}{r^2} : \frac{m'}{(r'-r)^2} :: \frac{m'}{(r'-r)^2} : \frac{2(r'-r)}{r^3}.$$

Put $r' - r =$ radius of the sphere of activity $= R$, and we have

$$R = r \sqrt[5]{\tfrac{1}{2}\, m'^2}$$

The following table gives the value of R for the principal planets. It will be seen that the four outer planets have large spaces around them in which the attraction of the planet is the controlling force. That of Neptune extends to more than half the distance of the Earth from the Sun.

Planet.	*R.*	Planet.	*R.*
Mercury	0.0006	Jupiter	0.2805
Venus	0.0035	Saturn	0.3174
Earth	0.0054	Uranus	0.3027
Mars	0.0034	Neptune	0.5044

CAMBRIDGE, Mass.
1899, March 18.

ASTRONOMICAL MYTHS—THE PLANETS AND THE WEATHER.

THOS. LINDSAY.

FOR POPULAR ASTRONOMY.

It would offend some very good people who have done us no harm if we made the plain statement that the idea of the planets ruling the weather is the same as a belief in astrology. It is true there are wet and dry planets and signs of the zodiac, according to Zadkiel, but there are thousands to whom that author is unknown who firmly believe in a connection between the weather and the position of the heavenly bodies other than the Sun. So far then from saying a word to offend these good friends, we will admit that the myth is a most respectable one. Whoever believes in it must know that there are planets revolving about the Sun and that in itself is something. We fancy, too, that the myth is a comparatively modern one, or at least has been of recent years revised, for the very earliest observers lived in a clime where constantly changing weather was not the rule. It is, therefore, a myth quite up-to-date, and eminently worthy of notice.

The cult in brief is this: the principal planets of the system affect the meteorology of the Earth according as they are placed relative to each other and the Sun. But strange to say they do not affect those parts of the Earth where the weather is extremely regular; where it is not a topic of conversation. It is always cold at the poles and pretty warm on the equator; the African desert is burning hot, arid, all the time; the mariner bound around the Cape knows just what to expect, and gets it; he had it last trip and the trip before, at the same season. No, it is only where the weather is changeable, as commonly understood, that the planets find field for their influence. Jupiter and Saturn are in opposition to the Sun; something will happen in the temperate zone, around the New England states for instance. The other zones are serenely indifferent to any configuration. They are obedient only to the Sun.

However, it is not by laughing at a myth that we can dispel it. We must show some common sense reason why is should not be entertained. Even then we are not sure of success; but let us try. It is evident in the first place that any rules connecting the planets and the weather must be the result of long observation. Physics has not been brought in by way of explanation. It is not so in the case of the Sun. We might imagine a stranger from the confines of the universe, gifted with a knowledge of natural phenomena, coming to our little system for the first time. He would see at a glance that the solar rays must fall more fiercely upon one part of the Earth than on another according to how much of the atmospheric envelope intervened. But who has given a reason why Jupiter should make the temperature rise or fall? Observation then alone can assist in forming a theory to guide the planet and weather prophet. And where, we must ask, is the series of observations to be found, establishing the theory that Jupiter affects the weather in such and such a way? True, we may be reminded that not Jupiter alone but all the members of the family have to do with it. That only makes it worse. Where is the Methuselah who has spent a thousand years in noting the endless configurations of the planets? Nay, given one configuration, whoever saw the same again among the planets? Well, nobody; and why should we be asked to credit for a moment the theory which some one has evolved out of a capacious brain! We might be met with the reply that configurations of a general similarity do happen often enough and that it is not necessary to have positions down to degrees. We admit this. Then we may be told that the weather is not predicted very minutely, and that a large extent of country is provided for. There they have us every time! "About—this—time—look—out—for—snow—and—ice." That is what the youngsters do every Christmas, regardless of Jupiter. "During the passage of Mercury across the Sun, in July, there will be an extremely hot spell, lasting three days." Now who ever met a July in this country that did not have three hot days in it, consecutive, too? But the days are named and they coincide. Remarkable, at first thought; let us look into it. Say that Mercury affects the temperature in this way for three days while he approaches crosses, and passes beyond the Sun. Now there is one fact which no weather prophet will deny, that for any given locality the average temperature is the same within very small limits, year after year; any given period then must be either normal, below, or above. We predict one or another and have

two chances to lose and one to win. That is to say, we will strike it once in three times. This guessing is close enough to make the reputation of any almanac maker in the country. Then again, consider the locality; if it is not hot on those three days in one place it will be in another, and as there are a good many "others," the prediction is verified somewhere every time. Have we not all experienced miserable weather, rain and hail, while our friends a few miles away were picnicking under a serene sky?

In fact the law of probability works for the weather prophet as it does for Zadkiel. "You will be happily married and live long, but you must guard against the evil influence of Saturn." "The 15th of July will be an excessively hot day but you must be in the right spot to experience it."

Can anything be more supremely ridiculous than this? Let us see a table of a thousand passages of Mercury side by side with a thousand high or low temperature (whichever is claimed) and if there is even a reasonable number of coincidences we will consider it worthy of investigation; but where is the series? Of course Mercury does not do all the work, the other planets affect (just as Zadkiel has it), and the same weather or peculiar change will not occur at every conjunction. Then as before, we demand a list of the millions of other configurations.

With the origin of this planet and weather myth we are not specially concerned. What is painful is the fact that it is widespread. Some one has an honest desire to learn something of nature's ways and starts out to investigate; in an evil hour he reads that all the meteorologists are at fault, they can only tell you the weather for to-morrow; the planets are the rulers, and their motions can be predicted years ahead; He wonders what sort of a thing it is that comes from Jupiter to make the day fine or cloudy; racks his brains in the effort to form a mind picture of the influence, while the Sun, disregarded, is pouring his beneficient rays upon him; then, most unfortunately, that "sense of mystery," which should have been destroyed ages upon ages ago, is touched, and he is again—a primitive man! The thing is mysterious, awe-inspiring; out in the depths of space there are bodies bound to us by wonderful bonds, they rule everything; he cannot understand it, but it must be so, and there is an end of all investigation. Then the downward course is rapid; common sense, which does not fail him in other matters, would not fail him here, but he will not give it a chance; it is mystery he wants, and mystery he gets, enough and to spare, in all conscience.

It is really sad to think that even in these enlightened days there are minds which stubbornly refuse to follow nature where nature is obviously simple in her methods. We do not say that meteorology is an easy science, but there is surely evidence enough to direct us to a study of the Sun alone; we know what causes the seasons, why go hunting around in the depths of space for the cause of occasional wet days and so on? It is just possible that the weather prophet takes his stand among the planets because he thinks it difficult to overturn him there; so it would be if he had any right to so entrench himself, but we insist upon knowing the line of thought that carried him there, we want to see the list of observations. And at the same time we want to be sure that our friends are not twisting the probability theory to suit themselves; coincidences are easily found if we look for them, and as many of one class as of another. For every time that an opposition of Jupiter accompanies cold weather, we will find one where the exact reverse is the case. A very little of this double dealing on the part of the thunderer is enough to make us suspicious of him.

It yet remains to consider the effect which the Moon is supposed to have. Here we are at no loss for observations. The only way to convince one of the non-interference of the Moon is to set down her changes side by side with a meteorological record. The stubborn regularity of the figures in the latter, within certain limits, and the total lack of order in the little irregularities, are seen together with the regular periodic changes of the Moon and anyone who can formulate a law out of these observations can prove anything.

We greatly fear however that there is no real desire to investigate these matters on the part of the weather prophet. There is nothing mysterious about Observatory records or almanac columns. Anyone can refer to these; give the people something and call it strange, play upon the oldtime "nature of the base" and you have them.

NOTES ON THE INVENTION OF THE TELESCOPE.

D. W. EDGECOMB.

FOR POPULAR ASTRONOMY.

The sources of information regarding the history of the invention of the telescope have been probably as thoroughly explored as any subject of scientific history. And there can be no question, as a result of the study, that the ancients knew absolutely noth-

ing of the instrument or of the optical principles upon which its construction depends. In all probability the little spectacle shop of Jansen or of Lipperhey, in the Dutch city of Middleburg, was the true first cradle of this wonderful instrument, the greatest that the genius of man has ever yet devised; and the conquests of which, when transferred while yet an infant, to beneath the skies of Italy, exceeded by an almost infinite measure, anything which the ancient imagination could conceive as the labors of its infant Hercules.

A few passages have been found in the ancient writings which seem to indicate that the magnifying effect of glass globes had been observed, and also the property of condensing the Sun's heat by crystals of a certain shape.

In Aristophanes' comedy, "The Clouds," mention is made of burning glasses. Pliny states that physicians cauterized by means of crystal globes. Anaximander says that fire may be produced by the rays of the Sun passing through a vase filled with cold water; and Seneca also says that objects though small and indistinct are seen larger and more distinct through a globe of glass filled with water.

Now the remarkable thing with reference to these and a few other similar passages is that the ancients, with such phenomena before them, should never have learned the property of a lens, or conceived the idea of making one. Had any one among them ever made a lens and acquired a knowledge of its properties, it would certainly have been fully recorded and highly celebrated, as nothing ever made or done in antiquity was so important. Our surprise is increased when we consider the extent to which the manufacture of glass had been carried, especially by the Romans. The considerable collection of articles in the British Museum, some dating as early as 500 B. C. with the trade marks of the different manufacturers upon several pieces, show that competition was actively at work, and had produced the usual diversity and improvements in the arts.

The story of Nero's emerald, which for so long a time figured in the list of items illustrating the ancient optics, appears to me capable of a natural and probable interpretation. The gem, like any similar object with a polished surface, has the property, when held in the right position before the eye, of giving a miniature reflection of neighboring objects, as the arena and its contents, and the Emperor might well have amused himself by trying to follow, in the infinitessimal reflected image, the movements of the combatants or other moving objects there, and so give rise to the be-

lief that he looked through the stone at the scene before him. Whether the surface were flat, convex, or as the story says concave, it would be equally impossible to see distant objects by means of it so well as by the naked eye.

The ancient optics by reflection are so scanty as to be practically *nil.* We read that there was a mirror in the tower at Alexandria—the *pharos* of the seven wonders—giving a picture of the horizon and distant ships. This is quite possible, but they were certainly never seen nearer, larger and more distinct. Had there existed at Alexandria or at Athens or Rome a device producing such a result, the world would have been filled with the knowledge of it. It would not have taken long for the sailors of Tyre, of Carthage or of the Grecian colonies of the Archipelago to conclude that such an instrument would be as useful to look from sea to shore as from shore to sea. Think how the story went from end to end of Europe in Galileo's time, of a tube that had been made in Holland, with a glass in each end, whereby distant objects were brought nearer and seen with correspondingly increased distinctness. The researches of the many seem to show that telescopes made by Lipperhey were in the hands of others as early as the month of October, 1608. A patent was refused, as is well known, to one of those who claimed the invention, on the ground that it was already known to others; and the effort or proposal by the State's General to keep the knowledge of the instrument for the use of the government in war, was ineffectual. "The French envoy wrote to Sully on the twenty-eighth of December, 1608, that he was in negotiation with the maker at Middleberg for an instrument for the King, Henry IV. Simon Marius, who claimed to have discovered the Satellites of Jupiter, tells us that in the Autumn of the same year, at Frankfort on the Main, a Belgian had offered a telescope for sale to one of his friends. They were made in London in 1810, a year after Galileo had made his."*

The only object that has been found among the ruins of any ancient nation bearing the remotest appearance of having been designed or used for optical purposes, is the piece of rock crystal in the British Museum. This was found by Layard among the ruins of the palace of Nimroud and is therefore Assyrian. Its date is considered to be about 700 B.C. Sir David Brewster was of the opinion that it was a lens. It is approximately plano-convex, oval in shape, about 1½ inches long, 1 inch broad and $\frac{3}{16}$ inch in thickness. He found that it could condense light, and has a focus of about 4½ inches. It is not, however, generally agreed

* Flammarion, *Copernic*, p 107.

that Sir David's surmise as to the purpose of the crystal is correct. An examination will, I think, convince anyone that its form is most probably accidental, and it is certainly too opaque now to be of any use whatever as a lens.

Had the Greeks and Romans any idea of a lens and its properties, they would have made spectacles for the impaired vision of the aged, as was done at a later period. This was evidently the first use to which the knowledge of lenses and the art of making them were put. It seems to be almost certain that they were known and occasionally used at the beginning of the 14th century. Indeed, the desire to preserve the faculty of sight, as age brings impairment, would lead to the eager demand for this great boon as soon as its existence became known; and it is certain that the knowledge when it had been once attained, would never be lost. Doctor Johnson, in remarking once that, as a rule, those persons who had conferred real and lasting benefits upon mankind, were either forgotten or ignored, gave as an illustration the case of the inventor of spectacles, of whom, he said nothing was known. Roger Bacon died in 1292*, and if the expressions which are found in his *Opus Magnus* really refer to spectacles, they probably afford the earliest record of their existence in the world. The passages refer to the magnifying effects of segments cut from glass globes; they but doubtfully refer to spectacles and at any rate they convey no claim on his part to his having been the inventor. They were known in Holland at no very long period after the death of Bacon. The only, or at least the earliest, direct claim on statement as to the author of the invention was embodied in the tombstone inscription in the church of St. Mary at Florence, by which Salvini degli Armati who died in 1317 was designated as the inventor. Arago, who I believe first mentioned the inscription, says, however, that it no longer exists, which seems very singular, as Flammarion† apparently refers to it as though it existed. Dr. Johnson evidently was not aware of it, as its quaint form would probably have called from him some characteristic remark.

During the long period of three hundred years that passed over Europe, from the beginning of the 14th to the beginning of the 17th centuries, while spectacles were known and used, it seems very remarkable that the simple combination necessary to form the telescope was not hit upon, either by accident or by reasoning, or by one supplementing the other as in the case of Galileo afterwards. But there was needed the discovery of one

* *Copernica* p. 108.
† Some authorities give this date as 1294.—Ed.]

great principle, the one underlying fact which it was necessary should first find its way into the mind, and that is the formation of an image by a lens of the objects situated in front of it; and still further that this image, though immaterial, can be magnified as though it were a material object. That a lens could produce a picture upon a screen, it would seem must have been an early discovery when lenses had once come into general use for spectacles; although so far as we know, even this was first known or made use of, by Baptista Porta, in his camera obscura, who was born in 1545, two years after the publication of the great work of Copernicus, from which latter event, so great is its importance, it seems to me all modern astronomical dates ought to be compared and referred. Now Porta, like Fracastor* at a somewhat earlier period, came near to the discovery of the principle of the telescope, when he observed that two lenses placed together magnified more than one. Flammarion has an interesting note upon this point:

"A somewhat remarkable fact bearing upon the invention of the telescope is to be found in the life of Fracastor. In his theory of the visibility of the planets, he explains the variations in their light by stating that their images are magnified in passing through denser media. This explanation is curious. Spectacles to assist imperfect vision had been known for two centuries. Fracastor, in verifying the theory that the density of a transparent medium magnified objects seen through it, observed that the increase in size is in proportion to the density of the medium: when objects are seen in water those at the bottom seem larger than those at the surface. Fracastor then states that if objects are viewed through two spectacle glasses placed together they appear larger than when viewed through a single one. At this point he came near to the theory of the telescope; he had but to separate the two glasses. But a century was destined to roll away before it could be done. Why did not this idea present itself to Fracastor? We cannot tell. The step seemed easy enough to take, but it was not one that could be taken by mere chance. Chance does not create; it causes the ripe fruit to fall, that is all. The idea, the discovery which may seem to be conceived suddenly, and which we may believe to be spontaneous, has a thousand roots in the past. Those which are not ripe must wait their season, as the seeds which are sown together in the same earth, develop successively under different influences."†

* Fracastor was born in 1483, eleven years after Copernicus.

† Copernic, p. 107.

It might fairly be said that they had the telescope in their hands but not in their minds. And indeed the same might be said of every one who during that long period had occasion to note the combined effect of two lenses. As Flammarion says "it was only necessary to separate the two lenses," though to this it must be added that it was necessary they should be unlike. But having eyes they saw not. This seems especially singular in the case of Fracastor and of Porta, who brought both experiment and reasoning to bear upon the subject. Similarly Newton, in 1762, had the lines of the solar spectrum before him, and had in his hands the spectroscope; but his eyes were unopened and the knowledge did not come until a century and more afterwards, to Wollaston and Fraunhofer. So Fracastor and Porta failed to discover the image at the focus of the lenses they experimented with, and it required another century, to be found finally by the spectacle maker of Middleburg.

The familiar story of the children of Jansen, who by accident placed two lenses in position one behind the other and looking through both saw the church steeple nearer and larger, though unsupported, would seem almost good enough to be true, as illustrating the discovery by such simple means and childish minds, of a great principle which studious minds had been unable to attain to for centuries with all the means at their command.

The facts regarding the actual invention seem to me to be, that the compound microscope was invented by Jansen in 1590, and the telescope by him and Lipperhey in 1608. In this way we can reconcile the conflicting statements as to dates.

It was the construction of the first compound microscope by Jansen in 1590 that really marks the great epoch in scientific history. The telescope was certain to follow directly, for the same principle is involved in each. The idea that an image formed by one lens could be magnified by another was first embodied in Jansen's microscope, and all modern optical instruments are founded upon it. This first microscope consisted of two convex lenses. One of these instruments made by Jansen was found at Middleburg in 1866. It was loaned for the South Kensington exhibition in 1876 and some copies were made, one of which is, I think at South Kensington, and one in the army medical museum in London.

Another thing may be mentioned as somewhat remarkable, that in the long period between the fourteenth and seventeenth centuries, when spectacle glasses were known and used, no one should have discovered that objects may be brought nearer by

the use of a single lens. If a lens of long focus be placed at a sufficient distance from the eye, it forms with that organ, a telescopic combination, the power of which depends upon the relations of the focal lengths of the lens and the eye. Probably something of this kind was referred to by Dr. Dee, in his preface to Euclid's elements, published as stated in Chamber's Hand Book of Astronomy, in 1570, when he speaks of the help in seeing distant objects afforded by "perspective glasses." There seems to be no other way of explaining this expression. There is one pretelescopic reference to the telescope which seems to me to be wholly and absolutely perplexing: It is that of old Leonard Digges in his "*Pantrometria*," published in 1571, which states as quoted by Chambers,* that "by concave and convex mirrors of circular and parabolic forms, or by pairs of them placed at due angles, and using the aid of transparent glasses, which may break or unite the images formed by the reflection of the mirrors * * a small object may be discerned as plainly as if it were close to the observer, though it may be as far distant as the eye may descrie." And this was reiterated by his son Thomas Digges, in even more extravagant language, in the second edition of the work, published in 1591. Now if these perplexing passages contained a description of the refracting telescope they might fairly be considered as anticipating the Middleburg inventors and Galileo, in view of the existence of spectacle lenses at the time; but they really give an almost complete and fairly correct description of the essential parts of the reflecting telescope, given, it is to be observed, 68 years before Mersenne first suggested the use of a mirror for the purpose, 92 years before Gregory made a similar suggestion and more than 100 years before Newton made the little telescope, the precursor of the giants of Herschel and Rosse, and which stands on the desk of the secretary of the Royal Society in London, by the side of the original manuscript of the *Principia*. That any such combination as Digges describes could have existed when he wrote the above passage, outside of his imagination, may well be pronounced impossible; for it is well-known that Gregory was unable, 90 years afterwards, to find in London any workmen who could undertake to make such an instrument as he had devised. We know also that Newton in 1670 had to construct his with his own hands, as Hooke did in 1674, Hadley in 1718 and Molyneux in 1738. It was not until after this last named date that workmen could be found in Lon-

* Handbook of Astronomy, 1890, Vol. II, page 292.

don intelligent enough even to receive and comprehend instructions how to make the instruments so that they could be obtained by the public.

The statement of Digges of 1571, embodying the description of an instrument which from all other evidence known to us there was not skill enough in the world to make, and did not exist until a hundred years later, should be placed by the side of a similar prophecy of Dr. Kitchener, contained in his book on telescopes, published in 1825, consisting of an almost equally succinct account of the "Equatorial Coudé," which was not invented until about 60 years afterwards by M. Lœwy of the Paris Observatory. Doctor Kitchener says: "The observer may sit or stand in a warm room and without ever changing his position, observe more than half the horizon, the object appearing directly before him, however elevated it may be in the heavens; thus continuing in the easiest posture and without ever being exposed to the open air. No other telescope affords these very desirable advantages.*

It will be interesting to compare with the above, the following account of the "Equatorial Coudé," written by Chambers after seeing the instrument:

"The optical principle of the instrument consists simply in the light of the star to be observed being twice reflected by plane mirrors, so that the image is sent into a fixed eye-piece, with the result that the observer without changing his own position can point the instrument to any required part of the heavens, by merely shifting the mirrors and a part of the apparatus, he himself remaining stationary * * * * * The eye-piece reaches into the apartment of the observer, who, quietly and comfortably seated, observes by looking down a tube," * etc.†

While the compound microscope of Jansen, of 1590, which instrument first embodied the idea of the image formed by one lens being magnified by another, consisted of two convex lenses, the first telescope consisted apparently of the combination of a convex and a concave lens. If this was the case, it would appear that the telescope was invented independently, even though by the same person and not copied from the microscope. At any rate, the telescopes of Galileo were thus formed; and when we consider the great difficulty and the slowness with which optical

* Kitchener, *On Telescopes*, London, 1825, p. 105. It should be noted that Doctor Kitchener quotes this description from another, of a wonderful telescope, in which he—Doctor Kitchener—seemed to have little faith.

† Handbook of Astronomy, 1890, Vol. II., p. 109.

ideas had made their way in men's minds generally, the alacrity with which the great Italian grasped the principle, embodied it in an instrument, made improvements and turned it upon the infinite unexplored field of the heavens, excites our liveliest admiration.

It was thirty years after Galileo made his telescope that Kepler suggested the use of the convex eye lens, a natural result of the conception of an immaterial focal image which could be magnified. The idea was, however, original with Jansen and not Kepler.

The subsequent history of the telescope is so well known as scarcely to suggest further comment. The only other real improvement in the instrument was that of Hall and Dollond, which made the object glass approximately achromatic. The most perfect telescope of modern times is produced by the combination of the object glass of Jansen, Libberbey or Galileo, improved by Dollond, and the single convex eye-glass of Kepler, or rather of Jansen, and rendered also achromatic upon Dollond's principle.

There is one middle-age reference to the telescope which, although somewhat bizarre in its nature, has always seemed to me more interesting and worthy of a place among the historical notes than anything dug from the ancient classics. In that book of delight and instruction for old and young alike, the "Arabian Nights"—to keep to the brief familiar title—there is the story, or was in the old Edinburg edition which was long ago my own wonder companion, of the three princes who were sent by the king, their father, into distant countries, with instructions to bring with them on their return, each the most wonderful thing he should find in his travels. One returned, it will be remembered, with the magic carpet which transported its owner or whoever placed themselves upon it, wherever they wished to go; another brought the wonderful apple which cured all human ills, while the third found the mystic tube, which, says the story, was made of ivory, about a foot in length, and was furnished with a glass at each end. It showed the observer who applied his eye to the glass at the proper end of the tube, whatever he wished to see, no matter how distant it might be. That many of the strange and lovely impossibilities in this book, the greatest bequest, after the numerals of the Saracens to our western and partly civilized world, are founded upon some suggestive fact in nature or art, is generally recognized. The date of the Caliph Haran al Raschid, to whose reign these stories of the

night or of the early dawn, are generally assigned, was not long after the rise of astronomy among the eastern Saracens, on the building of Baghdad by the Caliph Al Mansur, usually referred to the year 762. Immediately preceding the reign of the great Haran was that of Abdalla Al Mamoran who had measurements made in Mesopstamia with a view to determine the dimensions of the Earth. If the story in question was not one of the earliest, but was added to the collection at a later date, there were many learned and ingenious men in succession among the Saracens for four hundred years from Haran to Abul Hassan and Hulagu, the grandson of Genghis Kahn, who may be conceived as having invented an optical instrument of the exact form described, and the performance of which might have been indicated in the highly imaginative account given by the author of the story. Abul Hassan, who made the catalogue of stars, about A. D. 1200, speaks in precise terms of tubes having at their ends "dioptres" for the eye and object; and this kind of instrument was in use at the Observatory founded at a little later period by Hulagu. If the Mohamedans had the invention, we can easily understand that it would not be a difficult matter on their part to prevent the knowledge of it from finding its way into the darkness of mediæval Europe.

Wandering through the halls of the Alhambra a few years ago, carrying under my arm in imagination the old book I have mentioned, I noticed the almost innumerable texts from the Koran mixed and interspersed among the elaborately traced patterns covering the walls, how some were too high and too small to be read by the naked eye, I wondered if the artists sent from Baghdad, at the request of Yusuf to decorate his palace, might not have brought with them one of the "ivory tubes" whereby he might examine the work as it progressed and when finished, while comfortably seated upon the ground below.

MYSTIC, Conn.

A GRAPHICAL METHOD OF FINDING THE ELEMENTS OF A PARABOLIC ORBIT.

F. R. MOULTON.

FOR POPULAR ASTRONOMY.

A number of methods of finding the elements of a parabolic orbit by the help of graphical constructions are known, the first having been devised by Newton. Like the methods of analysis they all make an assumption as to the heliocentric distances, and

then arrive at the final result by successive approximations. The one explained in this paper furnishes the final results directly, if there are six observations at the disposal of the computer; if there are but three, successive approximations are required.

Newton's method is given in the *Principia* Book III, Proposition XLI. In introducing it he says, "This being a problem of very great difficulty, I tried many methods of resolving it." The problem of finding the elements of a parabolic orbit no longer presents great difficulties to the astronomer; indeed from our modern point of view it is extremely simple. The analytical solutions are entirely satisfactory except that they are long in application and very tedious to one not accustomed to computing. From the way they are developed the work would be much facilitated if the approximate elements were known, and it is for the purpose of determining them that a graphical process might be of use if it were sufficiently rapid. There seems to be little occasion for short cuts in orbit work however, owing to the splendid industry of American and German computers.

The method given in this paper is in spirit similar to some of the methods employed in determining the orbits of double stars. The possibility of the process depends upon two theorems.

Theorem I: *The orthogonal projection of the parabola in which the comet moves upon the plane of the ecliptic is a parabola.* Consider the equation of the parabola with the origin at the focus (Sun), the x-axis coinciding with the major axis and the y-axis in the plane of the orbit. Denoting the parameter by p we have

$$y^2 = 2\,p\,x + p^2 \tag{1}$$

Let us rotate the x-axis backward through the angle ω, or until it coincides with the line of nodes. This will be effected by letting

$$\left\{\begin{aligned} x &= x' \cos\omega + y' \sin\omega \\ y &= -x' \sin\omega + y' \cos\omega \end{aligned}\right. \tag{2}$$

Then (1) becomes

$$x'^2 \sin^2\omega + y'^2 \cos^2\omega - 2\,x'\,y' \sin\omega \cos\omega - 2\,x'\,p \cos\omega - 2\,y'\,p \sin\omega - p^2 = 0 \tag{3}$$

Suppose the inclination between the plane of the ecliptic and the plane of the orbit is i, then we shall obtain the equation of the orthogonal projection of the orbit upon the plane of the ecliptic by multiplying the y' coördinate in (3) by $\cos i$. We find

$$x'^2 \sin^2\omega + y'^2 \cos^2\omega \cos^2 i - 2\,x'\,y' \sin\omega \cos\omega \cos i - 2\,x'\,p \cos\omega - 2\,y'\,p \sin\omega \cos i - p^2 = 0 \tag{4}$$

This is the equation of a parabola since the discriminant is distinct from zero, and the sum of the coefficients of the terms of the second degree in x' and y' form a perfect square. Q. E. D. It must be remembered that (4) *is the equation of the orthogonal projection of the orbit upon the plane of the ecliptic with the origin at the Sun, the x-axis in the line of nodes, and the y-axis in the plane of the ecliptic.*

Theorem II: Given six lines in the plane of the ecliptic and suppose that it is known approximately where a required parabola crosses them. Then but one set of six points (excluding certain possible exceptions) *can be found on these six lines in the vicinity of the known approximate positions, such that a parabola can be passed through them and lie in such a position that the radii to them from the origin shall include areas proportional to five given numbers.*

The difficulty of proving this theorem is such that only a brief sketch of the demonstration can be given in a popular article. Suppose the equation of the required parabola is

$$a^2x^2 + 2\,abxy + b^2y^2 + 2cx + 2ey + 1 = 0$$

In this equation the coefficients $a \ldots e$ are to be found. Suppose the given lines are

$$y = m_i\, x + n_i \qquad i = 1 \ldots 6.$$

Write the expressions for the intersections of the conic and lines, then construct the expressions for the areas between successive radii. Ambiguities in sign can, in general, be avoided from the knowledge of the approximate solution. Suppose the areas are respectively $A_1 \ldots A_5$. They are functions of known quantities and a, b, c and e. Let $\tau_1 \ldots \tau_5$ be the known quantities to which they are proportional. Denoting the factor of proportionality by $\varkappa$, we have

$$A_i = \varkappa\tau_i\,, \; i = 1 \ldots 5. \quad \text{Let } \frac{A_i}{A_{i+1}} = \alpha_i \text{ and } \frac{\tau_i}{\tau_{i+1}} = \sigma_i\,,$$

then we have

$$\alpha_i = \sigma_i \qquad i = 1 \ldots 4.$$

The σ_i are known and the α_i are functions of the four unknowns a, b, c, e. The α_i are composed of transcendental and algebraic terms, hence there is, in general, but one real solution for a, b, c, e. Suppose one desires to prove that the solution is unique in the vicinity of the approximate result. The approximate solution locates six points on the six lines. Suppose the

distances on the six lines of the exact solution from the approximate solution are respectively $\rho_1 \ldots \rho_6$, where the ρ's are unknown small quantities. Since four points define the parabola ρ_5 and ρ_6 can be expressed in terms of $\rho_1 \ldots \rho_4$. Then $A_1 \ldots A_5$ can be developed into converging power series in $\rho_1 \ldots \rho_4$ for sufficiently small $\rho_1 \ldots \rho_4$. Let the areas computed when $\rho_1 = \rho_2 = \ldots \rho_4 = 0$ be $A'_1 \ldots A'_5$. Then $\frac{A_i}{A_{i+1}} = \alpha_i$ are converging power series in $\rho_1 \ldots \rho_4$. Let $\frac{A'_i}{A'_{i+1}} = \alpha'_i$. α_i and d_i are known quantities. Let $\alpha_i - \alpha'_i = \beta_i$ then $\beta_i = F_i(\rho_1, \rho_2, \rho_3, \rho_4)$ where $F(\cdot)$ is a power series in $\rho_1 \ldots \rho_4$, and *vanishing* with these quantities. There are four known quantities β_i equal to four independent power series in $\rho_1, \rho_2, \rho_3, \rho_4$. The necessary and sufficient condition that $\rho_1 \ldots \rho_4$ may be expressed uniquely in converging power series in $\beta_1 \ldots \beta_4$ for small values of $\beta_1 \ldots \beta_4$ is that the functional determinant or Jacobian of the F_i with respect to the ρ_i shall be distinct from zero far $\rho_1 = \ldots = \rho_4 = 0$. This determinant is an algebraic function of m_i and n_i. The probability is infinitely small that such a set of values of m_i and n_i will occur that the determinant shall be equal to zero.

Let us apply these theorems. The comet moves in the parabola in such a manner that the law of areas is fulfilled, and this will be again true in the projected orbit in the plane of the ecliptic. Hence in order to find the projected orbit in the plane of the ecliptic we draw from the respective positions of the Earth at the six times of observation lines whose longitudes are equal to the observed longitudes of the comet at these times. We shall call these lines, which are the ones written $y = m_i x + n_i$ above, the longitude lines. We must now find six points on these lines such that a *parabola* (theorem I) can be passed through them and lie in such a position that the radii to the six points shall include areas between them proportional to the respective times of observation (Theorem II).

We shall find the parabola by trial. Construct in advance a system of confocal, coaxial parabolas so near together that intermediate ones can be interpolated visually. Then make the drawing for the special orbit considered on a semi-transparent piece of paper.

Draw the orbit of the Earth on a thin piece of paper to such a scale that its radius shall be about equal to the parameter of one of the intermediate parabolas in the prepared system. Direct the x-axis to the vernal equinox and mark the positions of

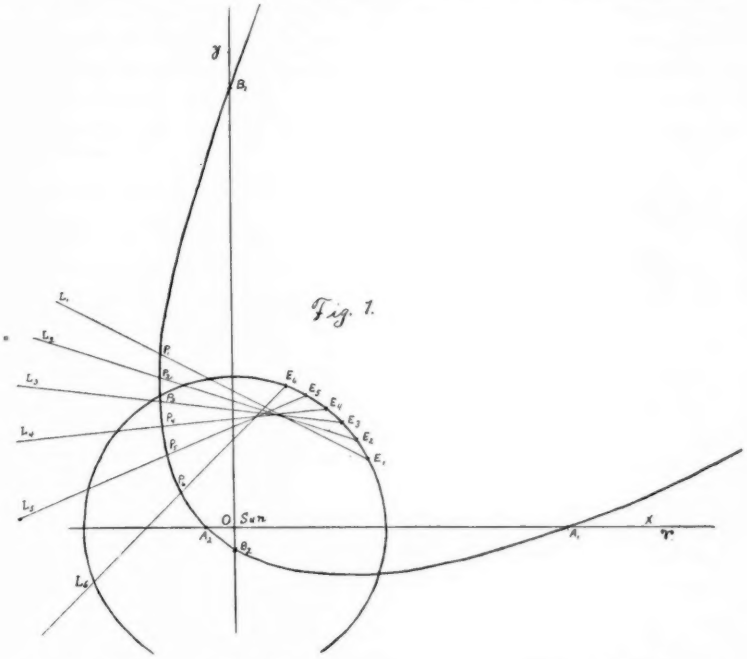


Fig. 1.

the earth $E_1 \ldots E_6$ at the respective times of observations. Lay down the longitude lines $L_1 \ldots L_6$. It is easy now to determine about where the parabola will cross $L_1 \ldots L_6$ by considering the velocities that the comet would have at different positions. If we let μ represent the attraction of the Sun at the unit distance measured by the acceleration it produces, V the velocity of a body moving in a circular orbit and U the velocity of a body moving in a parabolic orbit we have the well-known formulas

$$(5) \qquad \begin{cases} V^2 = \dfrac{\mu}{r} \\ U^2 = \dfrac{2\mu}{r} \end{cases}$$

Hence at the Earth's distance from the Sun a comet will be moving $\sqrt{2}$ times as fast as the Earth does. As it gets nearer the Sun its velocity will increase as the square root of the radius decreases. If the latitude of the comet and the change in latitude are both small we may apply the considerations just mentioned without modification. If the latitude is considerable or the

change in latitude rapid the motion in longitude, which alone appears in the figure, will have to be taken smaller than otherwise. Suppose that in the case for which we have drawn the figure the latitudes may be neglected. Then it is clear from the discussion of (5) that while the Earth is moving from E_1 to E_2 the comet must move from a point near P_1 to a point near P_2 and so on in the other intervals. This is the approximate location of the parabola mentioned in theorem II.

To find the exact location of the parabola lay the thin sheet, on which the longitude lines are drawn, on the system of parabolas and by trial find such a position for it that there will be a parabola passing near $P_1 \ldots P_6$ cuttting $L_1 \ldots L_6$ in such points that radii drawn from the Sun to them will enclose areas proportional to the times between the observations. Suppose the parabola drawn in the figure is the one which fulfills this condition. The areas are supposed to be measured instead of computed.

Let the equation of this parabola be

$$a^2x^2 + 2\,abxy + b^2y^2 + 2\,cx + 2\,fy - 1 = 0 \tag{6}$$

We must now determine the coefficients $a \ldots f$ from the drawing. Put y equal to zero in (6) and solve the resulting quadratic for x. Suppose the two roots are x_1 and x_2. That is $x_1 = OA_1$, $x_2 = OA_2$. Then by the theory of equations we have

$$x_1 x_2 = -\frac{1}{a^2} \qquad x_1 + x_2 = \frac{-2c}{a^2}, \text{ hence}$$

$$a^2 = \frac{-1}{x_1 x_2}, c = \frac{x_1 + x_2}{2\,x_1 x_2} \tag{7}$$

Let $y_1 = OB_1$, $y_2 = OB_2$ then we have similarly

$$b^2 = \frac{-1}{y_1 y_2}, f = \frac{y_1 + y_2}{2\,y_1 y_2} \tag{8}$$

To determine the sign of ab substitute the coördinates of any point not on one of the axes in (6). Thus (6) is entirely known. Suppose the longitude of the ascending node is the unknown quantity Ω. Let us rotate the axes forward through the angle Ω. It transforms (6) by the substitution

$$\begin{cases} x = x' \cos \Omega - y' \sin \Omega \\ y = x' \sin \Omega + y' \cos \Omega \end{cases} \tag{9}$$

Substituting in (6) we find,

$$\begin{cases} x'^2 (a^2 \cos^2 \Omega + 2\,ab \sin \Omega \cos \Omega + b^2 \sin^2 \Omega) \\ + y'^2 (a^2 \sin^2 \Omega - 2\,ab \sin \Omega \cos \Omega + b^2 \cos^2 \Omega) \\ + 2\,x'y' (-a^2 \sin \Omega \cos \Omega + 2\,ab \cos^2 \Omega \\ \qquad - 2\,ab \sin^2 \Omega + 2\,b^2 \sin \Omega \cos \Omega) \\ + 2\,x' (c \cos \Omega + f \sin \Omega) + 2y' (-c \sin \Omega + f \cos \Omega) \\ \qquad - 1 = 0 \end{cases} \tag{10}$$

This is the equation of the orthogonal projection of the orbit upon the ecliptic with the origin at the Sun and the x-axis in the line of nodes. This is precisely that which (4) represented hence the coefficients of the corresponding terms of the two equations can differ only by a constant factor. Call this factor λ, then we have

(11) $\lambda \sin^2 \omega = a^2 \cos^2 \Omega + 2ab \sin \Omega \cos \Omega + b^2 \sin^2 \Omega$

(12) $\lambda \cos^2 \omega \cos^2 i = a^2 \sin^2 \Omega - 2ab \sin \Omega \cos \Omega + b^2 \cos^2 \Omega$

(13) $\lambda \sin \omega \cos \omega \cos i = (a^2 - b^2) \sin \Omega \cos \Omega - ab(\cos^2 \Omega - \sin^2 \Omega)$

(14) $\lambda p \cos \omega = -c \cos \Omega - f \sin \Omega$

(15) $\lambda p \sin \omega \cos i = c \sin \Omega - f \cos \Omega$

(16) $\lambda p^2 = 1$

We have six equations for the determination of the five unknowns λ, p, ω, Ω and i, but we notice that (13) is the square root of the product of (11) and (12), hence there are only five which are independent. We may eliminate λ by means of (16).

Taking the product of (13) and (14), we have

$$\frac{\sin 2\omega \cos i}{p^2} = (f^2 - c^2) \sin 2\Omega + 2cf \cos 2\Omega$$

From (13) we have

$$\frac{\sin 2\omega \cos i}{p^2} = (a^2 - b^2) \sin 2\Omega - 2ab \cos 2\Omega$$

Taking the difference of these two equations

(17) $(a^2 + c^2 - b^2 - f^2) \sin 2\Omega - 2(ab + cf) \cos 2\Omega = 0$

From (11) and (14) we get

(18) $\frac{1}{p^2} = (a^2 + c^2) \cos^2 \Omega + (b^2 + f^2) \sin^2 \Omega + (ab + cf) \sin 2\Omega$

From (12) and (15) we get

(19) $\frac{\cos^2 i}{p^2} = (a^2 + c^2) \sin^2 \Omega + (b^2 + f^2) \cos^2 \Omega - (ab + cf) \sin 2\Omega$

(20) $\frac{1}{p^2} - \frac{\cos^2 i}{p^2} = \frac{\sin^2 i}{p^2} = (a^2 + c^2 - b^2 - f^2) \cos 2\Omega + 2(ab + cf) \sin 2\Omega$

From (17) and (20) we get

$$(21)\quad \begin{cases} \dfrac{\sin^2 i}{p^2} \sin 2\Omega = 2(ab + cf) \\ \dfrac{\sin^2 i}{p^2} \cos 2\Omega = a^2 + c^2 - b^2 - f^2 \end{cases}$$

Then the formulas are applied in the order (21), (18), (19) and {(14) and (15)} to determine Ω, p, i and ω respectively. It will be noticed that (21) does not enable us to determine whether Ω is less or greater than 180°, that is, we are not able to decide by this method which is the *ascending* node. This result could have been foreseen easily since all of our formulas would have been just the same if the orbit had been projected upon the ecliptic from the other side. If we agree with those who make the ascending node always less than 180° and count the inclination from 0 to 180° the indeterminateness is only transferred from the node to the inclination.

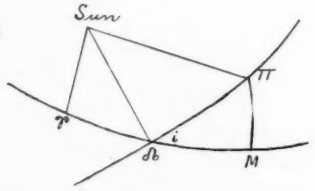
This ambiguity however will not cause the slightest trouble in practice, for while the comet is moving from the ascending node to the descending node its latitude is positive. Hence the whole question can be settled by knowing whether the comet has a north or south latitude at any given date.

The time of perihelion passage yet remains to be found. It can be determined as follows:

Sun Ω π is the plane of the orbit, Sun Υ Ω the plane of the ecliptic, π the projection of the perihelion point upon the unit sphere, M the projection of π upon the ecliptic. Then we have from the spherical triangle π Ω M

$$(22)\qquad \tan (M - \Omega) = \cos i \tan \omega$$

Fig. 2.



$(M - \Omega)$ is to be taken in the same quadrant as ω, hence M is uniquely determined. Draw the line whose longitude is M in Figure 1. The place where it cuts the parabola is the projection of the perihelion point upon the plane of the ecliptic. Suppose the times of two observations are t_1 and t_2 and the time of perihelion passage the unknown time τ. Let the radii at the respective

times be r_1, r_2 and ρ. Let the area between r_1 and r_2 be A_1, between r_2 and ρ, A_2. A_1 and A_2 are to be measured from the figure. Then we have by thelaw of areas

$$(t_2 - t_1) : (\tau - t_2) = A_1 : A_2 \text{ or}$$

$$\tau = t_2 + (t_2 - t_1).\frac{A_2}{A_1} \tag{23}$$

This expresses τ in terms of known quantities and completes the solution of the problem. It will be noticed that all the formulas are homogeneous of the degree zero in the units employed, hence it is immaterial what scale is used in the work. This method evidently works best when the inclination of the orbit is not very great and when the observations are made where the comet is changing its direction rapidly. Besides the observations must not be very close together.

In order to check the formulas they were applied to the determination of the elements of comet *h* 1898. The observations available were scattered over quite a long period of time and the motion was such as to be especially favorable to the use of such a method as that given above. All the elements were found correct to within one degree. In most cases results could not reasonably be expected anywhere nearly as accurate as in the orbit considered. The chief use of a graphical method anyway would be to give approximate geocentric distances at the times of observation, and it seems that the explanations given above would enable one to attain that much even in cases where the elements could not be found with any degree of precision.

THE UNIVERSITY OF CHICAGO.

February, 1899.

THE PHILIPPINE FIRMAMENT.

ROSE O'HALLORAN.

FOR POPULAR ASTRONOMY.

As henceforward there shall be much intercourse between this country and tropical latitudes, the strange scenes of an alien sky cannot fail to awaken interest in observant travelers both by day and night. A brief account of the most noticeable celestial phenomena may be convenient to those who have not leisure for the study of globes and star maps. Though specially adapted to the Philippine Islands, with a few modifications it will be

found suitable to the other newly acquired lands not so near the equator.

Commencing with daylight wonders, the strange sight of a northern Sun on the meridian at noon may be seen in the summer months, when the solar path lies in the constellations of Taurus, Gemini and Cancer.

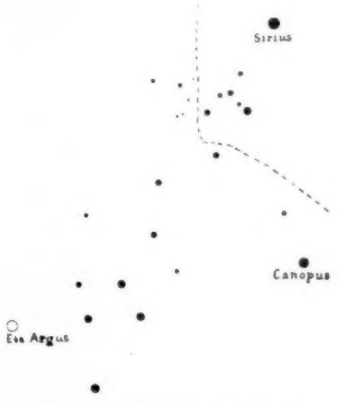
Manilla, in 14 degrees, 35 minutes north latitude, which will be the centre of travel in the farthest Pacific, has northward shadows at noon from the beginning of August to the beginning of the following May, just as middle latitudes in the northern hemisphere have during the entire year. Then, for a brief time, a zenith Sun causes no shadows, but soon small shadows glide southward, increasing each day in length until midsummer, and decreasing to zero in the beginning of August as the luminary again comes to the zenith.

Another peculiarity in these tropical days is the trifling difference in their length at midsummer and midwinter which is less than two hours. The charm of prolonged daylight, and nights of dismal length are alike unknown. Dusk and dawn are brief but beautiful intervals blending with the zodiacal light which becomes visible there in full splendor. This marvel of interplanetary space paints the track of the receding Sun in roseate hues just as dusk is ending, and in the morning the eastern horizon is the base of its triangular gleam as it ushers in the dawn.

Like the orb of day the Moon also when in Taurus, Gemini and Cancer is seen directly north when on the meridian. To those accustomed to observe the planets it will seem strange to turn to the north at times for Jupiter, Saturn or Mars. The Pole-star must be looked for pretty near the northern horizon, its altitude varying from about 13 to 16 degrees above it. The Lesser Bear, of which it forms the extremity of the tail, is the only constellation that never sets in the Philippine Firmament, as the region of perpetual apparition diminishes in correspondence with the latitude of the observer.

Planted on this tropic soil, the American flag greets a strange zone of sky to the south that rivals its own pictorial starfield, though less symmetrically bespangled. The south pole of the heavens and the few inconspicuous stars scattered near it are unseen, but all the interesting constellations and celestial objects not visible in the United States lie north of this region of perpetual occultation and come into view during the course of the year. To those lying between 40 and 70 degrees south declination, which are entirely unseen or but partially seen in the United

States, the following description is chiefly confined, a few modern constellations composed of inconspicuous stars being omitted.

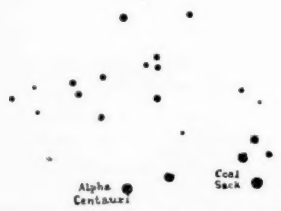


CONSTELLATION OF THE SHIP ARGO.

Commencing with the first meridian of the heavens and the evenings of March, the ancient constellation that commemorates the quest of the golden fleece very fitly greets the gaze of the enterprising voyager to this land of exuberant products. As the ship Argo glides across the meridian, its scattered stars of various magnitudes take up the chief portion of the southern sky near the horizon, and though not suggestive of a modern battleship, some antique device for ploughing the currents of the Hellespont may be easily traced in its outlines. Its principal orb, the brilliant Canopus, is the brightest fixed star in the heavens with the one exception of Sirius, the well-known dog star.

For guidance, the constellation of the "Greater Dog" is included in the accompanying diagram where a line marks its boundaries. The famous variable Eta Argus, which within two centuries has undergone amazing fluctuations, surpassed Canopus in 1843 and nearly equalled Sirius in brightness. But this gleam was not enduring, and after some years decreased gradually until it ceased to be visible to the naked eye. Its strange nebulous surroundings enclose a black starless space of keyhole shape, on the brink of which, the variable has waxed and waned, and may be still seen with telescopic aid as a reddish star of the 7th magnitude amid hundreds of other small orbs that also avoid the black vacuity. In April the Ship Argo continues to occupy the southern sky in the evening, though midnight and morning

bring other groups in view, but attention is called to those objects that are visible at hours convenient for general observation during the course of the year. In the evenings of May a luminous arc of the Galaxy unseen in more northerly latitudes spans the horizon towards the south and forms a glimmering background for the far-famed Southern Cross. This beautiful symbol appears slanting in the southeast at dusk and before 10 P. M. it rises to an upright position on the meridian. Though not enshrined in prehistoric faucies, and little known until the 17th century, its glimmer in the waters of the Earth is co-eval with that of the northern groups and it is the simplest and most impressive of the starry pictures. Close by, and in striking contrast to the brilliant scene around, is a wide black almost starless space, sharply outlined in the densest portion of the Milky Way. It has been long known to navigators by the name of the "Coalsack."*

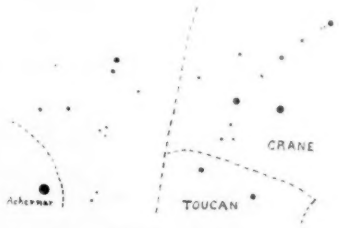


CONSTELLATIONS OF THE CENTAUR AND THE SOUTHERN CROSS.

That most grotesque of all mythological conceptions, the Centaur, comes to the meridian in the evenings of June and July. Rather imperfectly, the scattered group outlines the strange form, and the wolf that he is supposed to be in the act of spearing is still less suggestive of its name; however, two stars of the first magnitude, Alpha and Beta Centauri, add their lustre to this resplendent arc of the Milky Way. Of all the stars whose distances from the Earth are found to be measurable, Alpha Centauri has proved to be the nearest. So far, this would be the first port for a voyager on the ocean of space beyond the solar system. It is 265,000 times the distance of the Sun from the Earth. Telescopically it is a double star, both components revolving around their common centre of gravity in about 85 years. At 9:30 P. M. in July the "Southern Triangle," formed of one star of 2nd magnitnde and two of 3rd, is on the meridian

* Our engravers failed to bring out well the region of the sky about the "Coalsack" so called. The drawing was good.—ED.]

but very near the horizon, and the stars of Ara the Altar chiefly of 3rd magnitude appear in the southeast below the tail of the Scorpion. This latter constellation, though partly above the horizon of northern latitudes, has the favorable altitude of 45° when on the meridian of Manilla, and in the evenings of August and September will be the most conspicuous group in the firmament.



CONSTELLATIONS OF THE PHOENIX, THE CRANE AND THE TOUCAN.

The Southern Crown, a group of small stars scattered in a somewhat circular form, is on the meridian at 8 P. M. in September while in the southeast are the modern constellations known as The Indian, The Peacock and The Crane. The only conspicuous star in The Indian is of 3rd magnitude, and below it is one of 2nd magnitude marking the eye of The Peacock. At seasonable hours in October and November The Crane extends diagonally across the meridian, the Phoenix wings his flight there in the beginning of December, and the final curve of the River Eridanus streams westwards in the winter evenings the bright orb Achernar marking its southern boundary.

A new object of interest also appears at this season. The great Magellanic cloud emerges above the south point of the horizon for a short time, and if the atmosphere be very clear, may be seen to advantage at 9:30 P. M. in January and two hours earlier in February. Though entirely disconnected, it looks like a fragment of the galaxy that drifted away in the course of some cosmical re-adjustments, but telescopic investigation shows it to be a unique combination of stellar and nebular varieties.

The Ship Argo, before described, is then sighted in the southeast, thus completing the starry zone that henceforth shall gleam down on the starry flag as it waves over alien soil in the far Pacific.

SAN FRANCISCO,
February 17th, 1899.

THE SUN-DIAL OF AHAZ.

S. A. SAUNDER.

For Popular Astronomy.

In Popular Astronomy for February, p. 103, Dr. Morrison alludes to a letter in which I criticised the conclusions of his paper on this subject in the December number. My letter was not published, nor did I intend that it should be, but from what Dr. Morrison says it is clear that he has not appreciated the point of my criticism.

In his original article, on p. 544, Dr. Morrison puts $\frac{d \cot A}{dh} = 0$, and so finds the condition necessary that A should have a maximum value. If this is satisfied he concludes that the direction of motion of "the shadow of the style" will change its sign at the instants of the Sun's greatest eastern and western elongation. This is true if by "the shadow of the style" he means the edge at right angles to the plane of the dial, this being the line whose azimuth on the plane of the dial is equal to A. But it is not true of the shadow of the edge of the hypotenuse, which is the shadow that ought to be read in the ordinary use of the dial. The azimuth of this line on the plane of the dial Dr. Morrison calls θ. The treatment which I proposed, and to which Dr. Morrison objects, was to determine whether θ could have a maximum value by differentiating his equation (2), $\tan \theta = \sin \varphi \tan h$, φ being constant. This gives $\sec^2 \theta \frac{d\theta}{dh} = \sin \varphi \sec^2 h$, which shows that $\frac{d\theta}{dh}$ cannot vanish unless $\sec^2 = \infty$. But equation (2) shows that then $\sec^2 h$ also becomes infinite, and the equation for $\frac{d\theta}{dh}$ is indeterminate. To avoid this we put

$$\sec^2 \theta = 1 + \tan^2 \theta = 1 + \sin^2 \varphi \tan^2 h, \text{ by equation (2)}$$

Substituting in the equation for $\frac{d\theta}{dh}$ we find

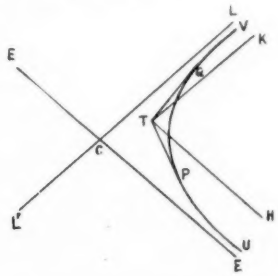
$$\frac{d\theta}{dh} = \frac{\sin \varphi \sec^2 h}{1 + \sin^2 \varphi \tan^2 h}$$

$$= \frac{\sin \varphi}{\cos^2 h + \sin^2 \varphi \sin^2 h}$$

$$= \frac{\sin \varphi}{1 - \sin^2 h \cos^2 \varphi},$$

from which it follows that $\frac{d\theta}{dh}$ can not vanish for any value of h, and therefore θ never attains a maximum value. In other words, the shadow of the hypothenuse can never regrede.

Dr. Morrison's explanation, therefore, requires the further assumption that those watching the dial directed their attention to the wrong edge of the shadow.



This also shows that Dr. Morrison is mistaken when he says on p. 102, of the February number, that "it makes no difference whether the edge which casts the shadow is perpendicular to the horizon, or leaning in any direction." He is also wrong in thinking that the shadow can only reverse its direction within the torrid zone. The following simple geometrical explanation will show how the phenomenon may be reproduced at any latitude, and on any day not too near an equinox. At any place at which the Sun rises and sets during 24 hours, the curve traced on the ground by the shadow of a fixed point will be (approximately) one branch of a hyperbola. Let $UPQV$ be the curve traced by the shadow of one end of a stick; let CE, CL be the asymptotes, and let the other end of the stick be put in the ground at any point T, between the curve and the asymptotes, so that two tangents TP, TQ, can be drawn from T to this branch of the curve. Draw TH, TK, parallel to the asymptotes. If the Sun rises in the direction CE',* the shadow of the stick is thrown along TH. As the shadow of its free end moves along UP, the shadow of the stick moves forward to TP; as the shadow of the point moves from P to Q, that of the stick moves backwards to the position TQ; after this it moves forwards again to the direction TK, when the Sun sets.

If the lower end of the stick had been placed at a point within

* The engraver omitted to mark the upper E in the cut properly. It should be E'.

either of the angles LCE', $L'CE$, from which only one tangent could be drawn to this branch of the curve, the direction of the shadow's rotation would have changed sign only once. If it had been placed at a point from which no tangent could be drawn, there would have been no change of sign. But if that point had been on the concave side of $UPQV$, the motion would have been entirely in the direction of the hands of a watch; if it had been within the angle $L'CE'$, the motion would have been entirely in the opposite direction.

The figure is drawn for a place in the northern hemisphere at which the Sun is above the horizon for more than 12 hours. The necessary modifications in the figure and description for other cases are easily made.

Finally, if the place be so near the pole that the Sun does not set, we have only to substitute an ellipse for the hyperbola.

It appears, therefore, that everything depends upon the direction of the stick.

WELLINGTON COLLEGE, Berkshire, England.

1899, Feb. 20.

THE VARIABLE STARS U VULPECULAE AND ST CYGNI.

EDWARD C. PICKERING.

The variability of the stars + 20° 4200 and + 28° 3460 has been announced, and the designations U Vulpeculae and ST Cygni assigned to them by Professor Müller and Dr. Kempf, of the Potsdam Observatory (*Astron. Nach.* 146, 37). Measures of these stars have accordingly been made by Professor O. C. Wendell, with the photometer with achromatic prisms attached to the 15-inch Equatorial of this Observatory. The star + 20° 4200 was compared with the star + 20° 4204, which is about 12′.6 distant. The results of these measures are shown by the heavy dots in Figure 1, ordinates representing magnitudes, and abscissas, phases, or intervals in days since the last computed maximum. The measures made at Potsdam are represented by the light dots connected by lines, and the dotted line shows the light curve given in the article mentioned above. The results for + 28° 3460, which was compared with + 28° 3467, distant 15′.0 are similarly shown in Figure 2. It will be seen that a smooth curve can be drawn, which would not differ on the average by more than one or two hundredths of a magnitude

from the points observed here. The greater accordance of the Harvard measures as compared with those made at Potsdam, is partly due to the greater number of settings made each night,

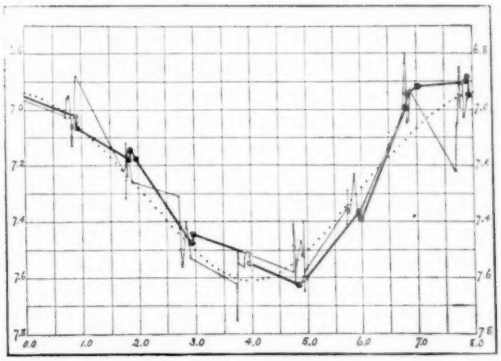


FIG. 1.

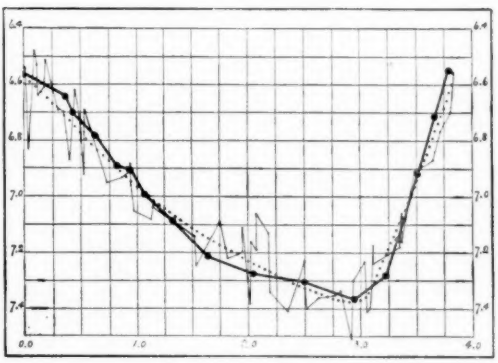


FIG. 2.

and partly to the smaller angular distance between the stars compared. At Cambridge, adjacent stars are compared directly, while at Potsdam, each star is compared with the standard stars by means of an artificial star. In drawing the light curve of + 20° 4200, too great weight seems to have been given to the Potsdam observation for which the phase is $7^d.7$, magnitude 7.22. Rejecting this, the other Potsdam observations agree closely with those made at Cambridge. To reduce the results to the same scale, the Cambridge magnitudes have been changed by + 0.16 and + 0.32, and the phases by $+ 0^d.8$ and $- 0^d.2$, in Figures 1 and 2 respectively. This indicates that the period of + 20°4200 is $7^d.98$ instead of $8^d.00$.

S Antliae.

The accuracy attainable with the photometer described above is illustrated by the following observations of the variable star, S Antliae. This star has a period of $7^h\ 46^m.8$, which is the shortest known, except in the case of variables in clusters. In Circulars Nos. 23 and 25, it was shown that the period of U Pegasi, which was at one time supposed to be shorter than that of any other variable, should really be doubled. The alternate minima were bright and faint, the difference in magnitude amounted to 0.15 and was determined with a probable error but little exceeding one hundreth of a magnitude. It, therefore, appeared important to see if S Antliae belonged to the same class of variables, and if its period should be doubled. A series of measurements was accordingly made by Professor Wendell on different nights near the times of minima, care being taken that some of the minima should correspond to an odd, and others to an even number of periods of variation, E. The comparison star was $-28°$ 7347, distant, 21′.8. A light curve was then formed from these measures, and residuals taken from it. On two nights E was odd, 11229 and 11349, and the means of the corresponding residuals were $+0.011$ and 0.000; on three nights E was even, 11306, 11340, and 11346, and the mean residuals were, $+0.004$, -0.007, and $+0.008$. The assumed value of the difference in magnitude of S Antliae when at minimum and $-28°$ 7347, was -1.676. Accordingly the mean difference in magnitude at minimum when E was odd, was -1.670, and when E was even, -1.674. It seems impossible that thousandths of a magnitude should have any real value, but if neglected, the accuracy of these observations would not be properly indicated. An error of two or three hundredths of a magnitude could not have failed to be detected. The variable star S Antliae therefore, does not have a light curve resembling that of β Lyrae and U Pegasi, and the period of variation should not be doubled.

Harvard College Observatory, Circular No. 41.
February 21, 1899.

SPECTROSCOPIC NOTES.

To the *Astronomische Nachrichten*, No. 3541, Professor Keeler contributes a note on "Variations in the Spectrum of the Orion Nebula." It was early suspected that the three bright lines in the green, characteristic of the spectra of gaseous nebulæ, did not retain the same relative brightness in different parts of the Nebula of Orion. The early observations seemed to indicate a variation, but were incon-

clusive. Professor Campbell from his observations at the Lick Observatory was led to state positively that the variation is actual. He specified in particular that in the brighter part of the nebula, near the Trapezium, the bright line at λ 5007 of unknown origin was the brightest; but that in the fainter part of the nebula about the star Bond 734 the *F* line of hydrogen (λ 4862) is the brightest of the three. Professor Scheiner, of Potsdam, while assenting to this statement of the appearance of the lines, disputed the reality of the variation, and attributed the apparent variation to physiological phenomena. It has long been known that in comparing a red source of light—such as a red line in the spectrum—and a blue, if they are equally bright for a certain intensity, then when both are diminished alike in intensity the red seems fainter than the blue; that if the intensity of both is further diminished the red will disappear first; that the blue will disappear only when the intensity has been reduced to a small fraction, a fifth, or even a thirtieth of that at which the red has been lost. This physiological fact has figured in the present discussion under the technical name of the 'Purkinje phenomenon.' By the Purkinje phenomenon Professor Scheiner accounts successfully for the failure to see in the spectrum of the nebulæ the *C* line of hydrogen in the red, which should be probably present when the *F* line of hydrogen in the blue is seen. He claims also that the variations in apparent brightness of the bright lines in the green are explained by this same Purkinje phenomenon; the line λ 5007, being toward the red from *F*, would decrease more in brightness in the fainter parts of the nebula, leaving *F* the brighter of the two. Other observers, using the spectroscope of the Lick Observatory, confirm Professor Campbell's observations of the apparent variation. Professor Runge, of Hannover, observing with the same instrument confirms the apparent variations; also, experimenting with Purkinje phenomenon, finds it striking, but with lines so close together as these in the green and blue insufficient to account for the variation observed. Professor Keeler in this communication to the *Nachrichten* describes his observation taken at the Lick Observatory on Dec. 22 with the idea of eliminating the Purkinje phenomenon. The night being hazy, in the faint part of the nebula only one line was visible in the spectroscope, and by direct comparison with light from a hydrogen tube this was identified as *F*. The slit was then placed near the trapezium, where the line λ 5007 was several times brighter than *F*. The intensity of the light was then diminished by contracting the vertical aperture of the spectroscope, and when this was carried far enough *F* disappeared and λ 5007 remained alone. Professor Keeler concludes:—

"In other words, with a sufficiently feeble spectrum the $H\beta$ (*F*) line was alone visible in one part of the nebula, and the chief line (λ5007) was alone visible in the other part. This result is inexplicable on physiological grounds. It can only be due to real differences in the spectrum of the nebula."

It is a matter for regret that photographs, such as that in the *Bulletin de la Société Astronomique* for February showing the resemblance of the spectrum of *o* Ceti (Mira) to that of third class stars and its variations from this type, do not more often find their way into publications of a popular character.

Sir Norman Lockyer read before the Royal Society on February 2 a paper on the "Origin of the Lines of α Cygni." In this star, intermediate in character of spectrum, and so probably in temperature, between the two great classes represented in Sirius and the Sun, he finds many of those lines of various elements which are 'enhanced' in the spark spectra of the elements as compared with their

arc spectra. He reserves for later publication an account of the elements considered individually. An interesting incident of the investigation is the introduction of the large induction coil formerly belonging to Dr. Spottiswoode, giving a spark of such luminosity as to allow the use of apparatus of increased power.

In *Nature* the same investigator announces that, from measures of photographs of spectral rings of the corona secured with the prismatic camera at the total eclipse of the Sun of January 1898 in India, he finds the corona line not at 1474 *K* (λ5316) where for a quarter of a century it has been supposed to be, but at λ5303, twice the space of the *D* lines away.

Astronomische Nachrichten, No. 3542 contains an article by Dr. Schultz-Steinheil entitled 'Die Rotation der Sonne.' He points out the fact that those, as Dunér or Crew, who have investigated the rate of the Sun's rotation by observing spectroscopically the motion of its parts toward or from us, have assumed the position of the Sun's equator as determined from the motion of sun-spots. He develops a method for deducing the position of the Sun's equator—inclination and node—from the observations themselves.

Mr. Berry in his well written and inexpensive elementary history of astronomy (A Short History of Astronomy, by Arthur Berry—New York, Charles Scribner's Sons) has allotted to astronomy in the nineteenth century, including the spectroscope, one chapter, about an eighth of the book. The problem of including the necessary material Mr. Berry solves by a change of style. The compact, dictionary-like style of the last chapter makes it very different reading from the free and easy earlier chapters, such as those on Tycho, and 'Copernicus.' The end is but 23 pages off when the spectroscope first appears, and of this small space it claims only part. In this brief spectroscopic summary there are of mistakes perhaps none; but it is hard to resist the impression that it is unsympathetic or unfamiliar. For instance after noting Maxwell's mathematical demonstration of the meteoric nature of Saturn's ring, the author remarks that this "has received a good deal of support from telescopic evidence, without a word about spectroscopic evidence." As a readable elementary history of astronomy the book should enjoy a liberal circulation among American readers, who, considering its British origin, will doubtless be patient with the customary Herschelian provincialism.

A committee appointed at the Harvard conference of August, 1898 have issued a circular with reference to concerted work at the total eclipse of May 28, 1900. The path of totality, reaching in this country practically from New Orleans to Norfolk, is so accessible that the attendance will probably be large. The committee remark that observers should remember that the totality is brief, $1^m\,13^s$ near New Orleans, $1^m\,30^s$ at the mountains, $1^m\,40^s$ near Norfolk. They inquire of the recipients of the circular as to their presence and their opinion of the proper character and plan of work.

Mr. W. H. Wright contributes to the *Astrophysical Journal* for February an orbit of the spectroscopic binary η Aquilæ. The fact of this star's variable motion in the line of sight was first established by Belopolsky at Pulkova. The variations in the star's motion toward and from us are periodic, and accompany systematically its complex fluctuations in brightness, but not in such a way as to

suggest eclipses. In making the necessary measures on the photographs difficulty was experienced from the indefinite character of the lines; and in every case a number of lines were measured.

It is interesting to consider the relation of the problem here presented to the more familiar problem of the orbit of a double star. If the line of sight is regarded as the axis of Z, there will be perpendicular to this on the sphere the axes of X and Y. Now a double star is determinable in both X and Y, two co-ordinates; a spectroscopic binary is determinable only along Z, one co-ordinate. Further, in the case of a double star, along its two determinable axes distances are measured; in the case of the spectroscopic binary, not distances at all, but velocities, are measured along its one determinable axis. The percentage of error in measuring the two distances for a double of average width is probably of the same order as the percentage of error in measuring the velocity in a spectroscopic binary of average swiftness. So far the advantage would seem to be with the double star orbits. But a double star even in a lifetime may describe only a small arc of its orbit, while the spectroscopic binary completes its revolution in a few days, and so is observed in every part of its orbit.

In this orbit of η Aquilae the probable errors assigned to the elements determined seem very small. For instance the eccentricity is given as 0.489 ± 0.014, surely a small enough error; while the position of perihelion, always a little indeterminate, is fixed to within about 2°. When the velocities computed from the orbit are compared with the velocities observed, the residuals average about 1 km. (0.6 mi.) per second.

In the same number Professor Campbell announces a variable velocity in the line of sight for the well known variable star ζ Geminorum.

It is stated in *Nature* of February 16 that at the anniversary meeting of the Royal Astronomical Society the gold medal of the society was awarded to Mr. Frank McClean for his photographic survey of stars in both hemispheres, and other contributions to astronomy.

VARIABLE STARS.

J. A. PARKHURST.

MINIMUM OF ALGOL. Mr. J. Bruce McCracken, of Ninevah Junction, N. Y., has sent me his observations, 11 in number, of the minimum of Algol, 1899, Jan. 19. The observations were made between $11^h\ 36^m$ and $14^h\ 34^m$ Greenwich time, and when reduced, give as the time of minimum,

1899, Jan. 19, $12^h\ 50^m$, Greenwich time.

The reduction to the Sun is $+\ 5^m$, giving for the heliocentric minimum,

Jan. 19, $12^h\ 55^m$.

The time of minimum according to Chandler's elements, Third Catalogue, is

Jan. 19, $12^h\ 7^m$,

According to Dr. Hartwig, the correction to these elements in September, 1898, was 44^m, which added to the ephemeris time gives,

Jan. 19, $12^h\ 51^m$,

in good agreement with Mr. McCracken's result, considering the small number of observations on which it depends.

MIMIMUM MAGNITUDE OF 7085 RT CYGNI. In POPULAR ASTRONOMY for October, 1898, page 473, I gave a list of the minimum magnitudes of this variable since 1895, and expressed the opinion that the coming minimum would be not brighter than $11^m.5$. But to illustrate what little dependence can be placed on such predictions, the actual minimum was passed 1898, Nov. 22, at $10^m.8$.

MAXIMUM OF U GEMINORUM. A note from Mr. Wm. E. Sperra, who is now at home at Randolph, Ohio, says that U Geminorum was bright Feb. 27. Particulars will follow later. We are glad that Mr. Sperra is again in position to continue his excellent work.

THE VARIABLE IN CASSIOPEA, charted in the April, 1898, number, page 118, has passed its minimum and is now rapidly brightening. It is especially adapted to telescopes without finding circles, being near *Sigma* Cassiopea. Its letter and number have not been assigned by Dr. Chandler at this writing.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1899.

U CEPHEI.

	d	h
May	5	14
	10	14
	15	13
	20	13
	25	13
	30	12

R CANIS MAJ.

Every 8th min.

$P = 1^d\ 3^h.3$

	d	h
May	1	12
	10	14
	19	16
	28	18

S CANCRI.

	d	h
May	25	17

S VELORUM.

	d	h
May	20	17
	26	15

δ LIBRÆ.

	d	h
May	1	11
	8	10
	15	10
	22	9
	29	9

U CORONÆ.

	d	h
May	1	16
	8	13
	15	11
	18	22
	22	9
	25	20

U OPHIUCHI.

Every 10th min.

$P = 20^h.13$

	d	h
May	5	6
	12	19
	21	4
	29	13

RS SAGITTARII.

	d	h
May	1	16
	6	12
	8	22
	13	18
	18	14
	23	10
	25	20
	30	16

DM + 12°,3557

	d	h
Apr.	3	22
	4	19
	5	16
	6	14
	11	22
	12	19
	13	17
	14	14
	15	11
	16	9
	19	22
	20	19
	21	17
	22	14
	27	22
	28	20
	29	17
	30	14

DM + 12°,3557

	d	h
May	5	22
	6	20
	7	17
	8	14
	9	12
	13	23
	14	20
	15	17
	16	15
	21	23
	22	20
	23	17
	24	15
	29	23
	30	20
	31	18

W DELPHINI.

	d	h
May	5	14
	10	9
	24	19
	29	15

Maxima and Minima of Long Period Variables.

1899.

MAXIMA.

		Mag.	June.
103	T Andromedae	7.7	15
715	S Arietis	9.1	4
1855	R Aurigae	6.5	1
1944	S Orionis	8.3	27
1981	S Camelopard.	8.3	7
2266	V Monocerotis	6.3	23
2445	W Monocerotis	8.8	12
2528	R Geminorum	6.6	5
3493	R Leonis	5.2	26
3567	V Leonis	8.6	27
3994	S Leonis	9.0	25
4377	T Virginis	8.0	5
4557	S Ursae Majoris	6.7	21
4847	S Virginis	5.7	25
4896	T Centauri	5.9	7
5237	R Bootis	5.9	6
5438	Y Librae	8.2	15
5501	S Serpentis	7.6	12
5830	R Scorpii	9.4	30
5950	W Hercules	8.0	17
5955	R Draconis	6.5	15
6894	S Lyrae	9.0	4

MAXIMA (Con't).

		Mag.	June.
7260	Z Aquilae	8.8	1
7431	S Delphini	8.4	25
7571	V Capricorni	9	29
7944	T Pegasi	8.5	27

MINIMA.

62	S Sculptoris	10.0	14
513	R Piscium	<13	7
294	W Cassiopeæ	11.4	28
845	R Ceti	13.5	9
893	U Ceti	12	17
976	T Arietis	9.3	19
1623	T Camelopard.	<12	22
1717	V Tauri	<13.5	28
1771	R Leporis	8.5	1
2013	U Aurigae	12	24
2213	η Geminorum	4.2	4
2539	R Canis minoris	10.0	12
5494	S Librae	<13	7
6062	RR Scorpii	10.0	17
6943	T Sagittae	9.9	1
7404	R Microscopii	12.0	28
7456	RR Cygni	9.7	3
7609	T Cephei	10.7	28

The star DM + 12°, 3557 is Sawyer's new Algol Type variable, for which a chart was given in the December 1898 number of POPULAR ASTRONOMY. It is now in position for morning observation and no time should be lost in confirming Mr. Sawyer's discovery and finding what correction, if any, is required for the period. The above ephemeris is based on the elements which Mr. Sawyer gives in *Astronomical Journal* No. 447. The position of the star for 1900 is, R. A. $18^h\ 26^m\ 1^s$, Decl. + 12° 32′ 36″.

The dates for the above maxima and minima are taken from Dr. Hartwig's ephemeris in the *Vierteljahrsschrift;* Vol. 33, except for the Algol type stars, R Canis Majoris, S Velorum, U Ophiuchi, RS Sagittarii and DM + 12°,3557, for which the ephemeris was computed from the elements.

CERASKI'S NEW VARIABLE IN AURIGA, charted in the January, 1899, number, page 43, has faded rapidly, and is now below 12 magnitude. The same is true for Anderson's variable in Cassiopea, charted in the February number, page 94. Anderson's new variable in Andromeda (see March, 1899 number, page 162,) has decreased more slowly, but the change is unmistakable, verifying the identification of the star as charted.

Another variable easily found is 6100 RV Herculis, charted in Vol. V, page 326. Its place for 1900 is, R. A. $16^h\ 56^m\ 45^s$, Dec. +31°, 22′.3. It is 17ˢ following, 18′ north of the 4th magnitude star, Epsilon Herculis. It is now rising towards maximum and calls for observation.

MAXIMUM OF MIRA.—The 51 observations of Mira by Mr. Hadden, given in detail in the February number, page 106, when platted, show a maximum at $2^m.6$ 1898, Oct. 4, and a secondary maximum at $2^m.7$ Oct. 23, with a drop to $2^m.8$ between the crests. When these fluctuations are smoothed out and a curve

drawn through the whole set, the maximum is shown at Oct. 15, $2^m.56$. This date is 324 days after the 1897 maximum, as compared with the period 331.6 days, given in the Third Catalogue. An inspection of the curve shows a slight tendency to estimate the variable brighter in the moonlight, as would be expected.

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury is at the eastern end of the loop in his path in Pisces April 1, (See January No. of POPULAR ASTRONOMY 1899 p. 37) and will move westward until the 24th. He passes the Sun at inferior conjunction on the morning of the 12th. The planet will therefore scarcely be visible to the naked eye during this month.

Venus is the bright "morning star," seen in Aquarius during this month, with no bright stars in the vicinity. Her phase is now gibbous, nearly three quarters of the diameter of the apparent disc being illuminated. The distance from the Earth has however been rapidly increasing, so that the brilliancy of the planet is now only one-third of that at the beginning of the year.

Mars will move southeastward from Gemini into Cancer during this month, the motion relative to the stars being easily noticed from night to night. Mars will be at quadrature, 90° east from the Sun, April 23. The planet should therefore be looked for in the early evening, to the west of the zenith. It is still brighter than the neighboring stars and conspicuous because of its ruddy color.

Jupiter is to be seen toward the southeast late in the evening and may be be best observed about midnight. This planet is retrograding slowly between Libra and Virgo, and far exceeds in brilliancy the fixed star Spica, which is about 15° to the west of the planet. Jupiter will be at opposition on April 25.

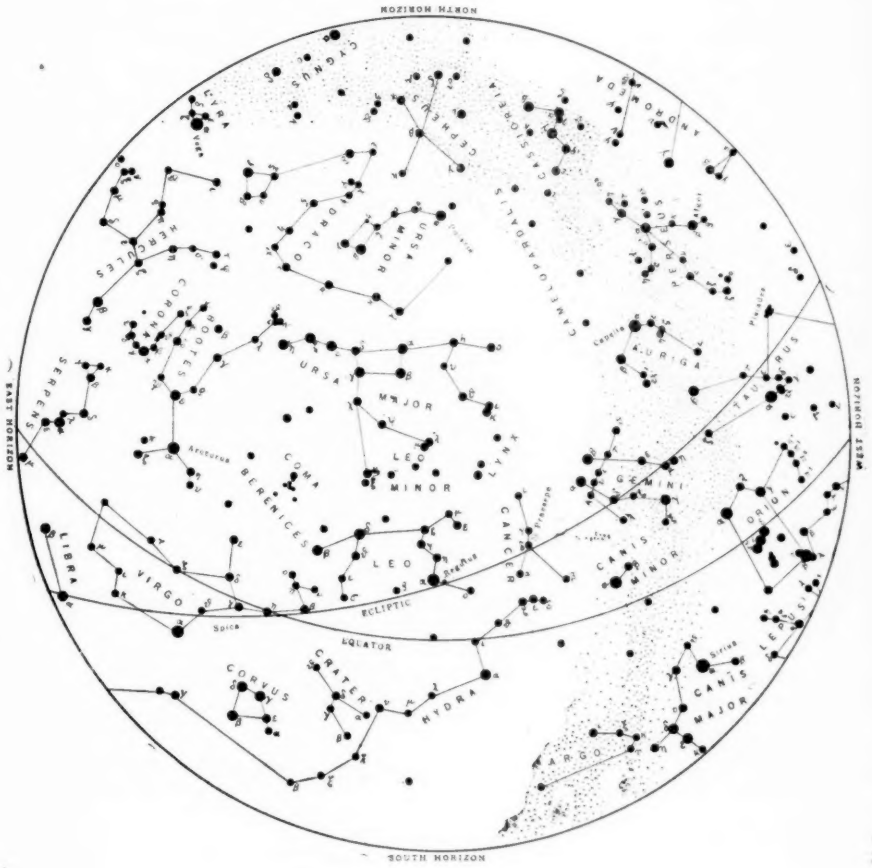
Saturn may be seen in the morning, about half way between Jupiter and Venus, Jupiter being toward the southwest, Venus toward the southeast, and Saturn near the meridian toward the south at 5^h A. M. Saturn's motion will be hardly noticeable during the month, but its yellow color will enable one to easily distinguish the planet from the stars in the vicinity.

The remarkable announcement is given, in another place, of the discovery of another satellite of Saturn by Professor W. H. Pickering, of Harvard College Observatory, increasing the number of the known retinue of the planet to 9, besides the myriads of lesser attendants which constitute the wonderful rings. The new satellite, if the estimates of its magnitude are correct, can only be seen with the most powerful telescopes.

Uranus is in Scorpio, between Jupiter and Saturn, and therefore to be seen in the morning. It can be seen only with the aid of a telescope.

Neptune is past its best position for observation, but may be seen with a good telescope in the early evening.

A large sun-spot has been upon the solar disc during the last two weeks.



THE CONSTELLATIONS AT 9 P. M., MARCH 1, 1899.

The Moon.

		Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.)		Sets.	
			h	m	h	m
April	3	Last Quarter	1	52 A. M.	11	4 A. M.
	10	New Moon	5	23 A. M.	7	53 P. M.
	17	First Quarter	10	55 A. M.	1	55 A. M.
	25	Full Moon	7	36 P. M.	5	14 "

Occultations Visible at Washington.

Date 1899.	Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle f'm N pt.	EMERSION. Washington M. T.	EMERSION. Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
April 1	63 Ophiuchi	6.6	13 39	122	14 42	243	1 4
2	ν^1 Sagittarii	5.0	13 6	39	13 49	315	0 43
2	ν^2 Sagittarii	5 1	13 46	12	14 4	341	0 18
2	B. A. C. 6448	6.4	14 7	160	14 25	191	0 18
7	16 Piscium	5.8	15 52	24	16 31	289	0 39
24	75 Virginis	6.0	7 11	177	7 45	240	0 34
29	B. A. C. 6343	6.3	12 35	110	13 32	243	0 57
30	*f* Sagittarii	5.2	17 16	21	18 12	293	0 56

COMET NOTES.

Two comets have been discovered during March, the first by Dr. Lewis Swift at Lowe observatory on March 3 as described below, the other by Wolf at Heidelberg March 5. Both are to be observed in the western sky in the early evening. Swift's comet quite bright and large, but should hardly be called a naked eye comet as stated in the discovery announcement. It can easily be picked up with an opera glass.

Wolf's discovery is a re-discovery of Tuttle's periodic comet, concerning which a historical note by Professor Pickering is given below. It is very faint, but can be seen with a five inch telescope. In our 16-inch telescope on March 8 it was about 1′ in diameter, with a slight central condensation.

The New Comet (*a*) 1899.—This was discovered at $7^h\ 15^m$ on the evening of March 3d, which I called bright. Its appearance was unlike any comet I have ever seen. It had two distinct comas, an inner bright one, and an outer, very large and exceedingly faint, one which I have not been able to see since, though carefully looked for. The outer atmosphere had an exact resemblance to that surrounding a nebulous star. It had a very short broad tail that was square on the end and opposite the Sun. On the evening of the 4th the seeing was poor and therefore I did not expect to see the outer coma, but on the evening of the 5th the seeing was excellent; as good as when the comet was found, but not a trace of the outer coma could be seen, which on the 3d, especially by averted vision, was very large.

The nucleus was star-like and bright. I have called it all along as being fainter than when first seen, but according to Professor Hussey's elements this could not be. Last evening, in presence of a crescent moon, its tail could be traced 15′ and doubtless would have appeared double that had the seeing been better and the moon absent.

The discovery place was partly made by estimation as I had been making some changes in the driving clock, etc. It was found by my 4½-inch comet seeker. LEWIS SWIFT.

LOWE OBSERVATORY, Echo Mountain, March 15, 1899.

Elements of Comet *a* 1899 (Swift).—The following preliminary elements of Swift's comet are all that are at hand. They were computed by Professor Hussey from his own observations at Lick Observatory.

POSITIONS.

1899 G. M. T.	R. A. h m s	Decl. ° ′ ″
March 4.6356	3 48 4.3	− 27 7 52
5.6478	3 42 12.6	− 25 36 54
6.6523	3 36 44.5	− 24 8 32

ELEMENTS.

$T = 1899$ April 13.26
$\omega = 4° 54'$
$\Omega = 23 9$ } 1899.0
$i = 146 4$
$q = 0.3447$

EPHEMERIS.

Greenwich Midn.	R. A. h m s	Decl. ° ′	Light.
March 8	3 27 8	− 21 34	1.00
12	3 10 12	− 16 23	
16	2 55 44	− 11 53	
20	2 42 56	− 7 55	1.15

By tracing these positions upon a star map it may be seen that the course of the comet has been through the constellation Eridanus and that it is now in Cetus not very far from the variable star Mira (*o* Ceti). The future course cannot be safely predicted without more accurate elements.

Tuttle's Comet.—This comet was discovered by Méchain at Paris in 1790. Only a few observations were taken, however, and the comet was rediscovered by Horace P. Tuttle at the Harvard College Observatory, Jan. 4, 1858.

Johannes Rahts, of Königsberg, made the most complete discussion of the orbit, combining the observations of 1858 and 1871-2, having regard also to the perturbations. His value of the period is 13.7 years. The comet was next seen in 1885, and was expected during the present year. An ephemeris was accordingly distributed from Kiel, and it was probably by means of this that a faint comet, supposed to be Tuttle's was discovered March 5 by Dr. Wolf, as already announced. This ephemeris, as corrected by Dr. Wolf's observation, is given below:

EPHEMERIS.

G. M. T.	R. A. h m s	Decl. ° ′
1899 Mar. 5.5	1 16 39	+ 31 36
9.5	1 31 31	+ 30 58
13.5	1 46 31	+ 30 16
17.5	2 1 35	+ 29 30

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, Mass. E. C. PICKERING.
March 8, 1899.

Ephemeris of Tuttle's Comet.—The ephemeris by J. Rahts in *Astronomische Nachrichten No.* 3552 has come to hand just as we are about to go to press. Although this is largely in error, we give the portion for April since there is nothing better in hand. The correction to this ephemeris, according to an improved ephemeris telegraphed by Rahts, was on March 9 + 17^m 9^s in right ascension and − 2° 9′ in declination. On March 29 the corrections amount to + 17^m 24^s and − 3° 30′. The correction in declination is changing uniformly 4′ per day, while that in right ascension has passed its maximum and will not be far from + 17^m during the first half of April.

Ephemeris of Tuttle's Comet.

1899	α app. h m s	δ app. ° ′ ″	log Δ	Ab.-Time m s	H
April 1	2 41 58.4	+ 27 53 58			
2	45 45.5	27 36 54			
3	49 32.3	27 19 26			
4	53 18.8	27 1 41	0.26748	15 22.2	0.96
5	2 57 4.9	26 43 34			
6	3 0 50.6	26 25 6			
7	4 36.0	26 6 17			
8	8 21.0	25 47 8	0.26603	15 19.0	1.02
9	12 5.6	25 27 38			
10	15 49.8	25 7 48			
11	19 33.5	24 47 38			
12	23 16.7	24 27 7	0.26464	15 16.0	1.07
13	26 59.3	24 6 17			
14	30 41.4	23 45 6			
15	34 22.9	23 23 35			
16	38 3.9	23 1 44	0.26330	15 13.3	1.12
17	41 44.3	22 39 32			
18	45 24.2	22 17 1			
19	49 3.5	21 54 10			
20	52 42.1	21 31 0	0.26198	15 10.5	1.18
21	56 20.0	21 7 31			
22	3 59 57.3	20 43 43			
23	4 3 34.0	20 19 37			
24	7 10.0	19 55 12	0.26069	15 7.8	1.23
25	10 45.4	19 30 30			
26	14 20.2	19 5 30			
27	17 54.4	18 40 13			
28	21 28.0	18 14 38	0.25939	15 5.1	1.28
29	25 0.9	17 48 47			
30	4 28 33.2	+ 17 22 40			

Elements of Comet 1898 VII (Coddington-Pauly).—The following provisional elements of this comet by C. J. Merfield are given in ***Astronomische Nachrichten*** No. 3546. Mr. Merfield requests that any unpublished observations of the comet be sent to him in order that he may use them in a definitive determination of the orbit. His address is "Royal Society, Elizabeth Street 5, Sydney, N. S. W."

PROVISIONAL ELEMENTS.

$T = 1898$ Sept. 14.052157 G. M. T.
$\omega = 233°\ 15'\ 36''.5$
$\Omega = 73\ 59\ 20.7$
$i = 69\ 55\ 57.0$
$\log q = 0.2308280$
$\log p = 0.5320216$
$\log e = 0.0003273$
$e = 1.0007539$

Elements of Comet *b* 1898.—The *Astronomical Journal*, No. 456, contains new elements, by Heber D. Curtis, of the comet discovered by Perrine at Lick Observatory, March 20, 1898. The computer obtains a period of 402.789 years.

ELEMENTS.

Epoch, March 20.0, 1898.0 G. M. T.

$M = 0° 0' 25''.4$
$\omega = 47 18 20.2$
$\Omega = 262 26 3.6$ } 1898.0
$i = 72 31 55.8$
$\varphi = 78 29 56.2$
$\log a = 1.736718$
$\log q = 0.039459$
$\log e = 9.991191$
$\log \mu = 0.944929$
Perihelion, 1898 March 17.11895 G. M. T.

Comet 1896 III.—In *Astronomische Nachrichten*, No. 3550-51, Mr. R. G. Aitken of the Lick Observatory gives a definitive determination of the orbit of this comet, which was discovered by Dr. Lewis Swift at Lowe Observatory on April 13, 1896. "During its apparition period, extending to June 20, the comet passed through a heliocentric arc of 105°—4° before perihelion passage and 101° after—and was measured more than 400 times at 37 different observatories." Mr. Aitken finds that the most probable orbit is an hyperbola, the eccentricity being 1.0004757, with a probable error of ± 0.00009985. Since, however, we find by experience that the real error is frequently as much as five times as great as the calculated probable error, it does not yet seem that we have a proven case of an hyperbolic orbit. The following are the hyperbolic elements with their probable errors:

$T = 1896$ April 17.6473143 G. M. T. ± 0.00057326
$\pi = 179° 59' 15''.40 \pm 3''.95$
$\Omega = 178 14 51.48 \pm 6.74$ } Mean equinox 1896.0
$i = 55 34 24.69 \pm 8.88$
$q = 0.5662857 \pm 0.00001347$
$e = 1.0004757 \pm 0.00009985$

GENERAL NOTES.

Dr. See appointed Professor of Mathematics in the Navy.—On Feb. 7 Dr. T. J. J. See was nominated to be a Professor of Mathematics in the Navy. The nomination was promptly confirmed by the Senate, and Professor See has already entered upon his duties at the Naval Observatory, Washington, D. C. It is understood that his future work will be along the line of Celestial Mechanics. We are sorry to learn that his researches on double stars will not be continued for the present.

In our last issue we mentioned a criticism of Dr. See's paper on the heat of the Sun. Up to this writing, he has taken no notice of it, and presumably he will not do so. The claim in his paper is so important that it will certainly soon get the attention of the ablest scholars in a dignified way.

A New Satellite of Saturn.—A new satellite of the planet Saturn has been discovered by Professor William H. Pickering at the Harvard College Observatory. This satellite is three and a half times as distant from Saturn as Iapetus, the outermost satellite hitherto known. The period is about seventeen months, and the magnitude fifteen and a half. The satellite appears upon four plates taken at the Arequipa Station with the Bruce Photographic Telescope.

The last discovery among the satellites of Saturn was made half a century ago, in September, 1848 by Professor George P. Bond, at that time Director of the Harvard College Observatory. EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, Mass.
March 17, 1899.

How Big Does the Moon Look to You?—I have been interested in a letter written by Mr. Arthur Mee F. R. A. S. published in the February number of the *Journal of the British Astronomical Association* on the above question which reminds me of the amusement mingled with astonishment I had one evening some 40 years ago by asking a party of visitors "how large in inches does the full moon look to them." It is needless to say I was surprised at the widely discrepant answers given. Mr. Mee's answer, however, in one direction surpasses those received by me.

He says she looks about the size of a three-penny bit. The following are a few of the answers I received: Size of a tea cup, five inches, ten inches, fifteen inches, two feet, thirty inches, forty inches, as big as a cart wheel. To my eye which has not varied from my youth up she seems to be about nine inches in diameter. I have never tested one on this point as seen through a telescope, or whether the distance between stars vary in like manner, but presume they do, and if so then the distance between horizon and horizon must also appear different to different persons, as well at the length of comets' tails and meteor trains. Is the cause susceptible of an explanation? LEWIS SWIFT.

ECHO MOUNTAIN, Cal.

Summer Courses in Astronomy at the University of Chicago.—The following announcements regarding the summer courses in Astronomy will interest our readers:

Outlines of Astronomy by Dr. Laves.—This course is intended primarily for those who do not wish to specialize along the lines of Astronomy or Mathematics. Special emphasis will be laid on the philosophical principles underlying the science of Astronomy, and on its relation to allied sciences. The course will be supplemented by occasional lectures by Professors Hale, Barnard, and Frost, and the students will be taken to the Yerkes Observatory and given an opportunity to make observations with the Yerkes Telescope.

The Fundamental Principles of Planetary Motions—Prerequisite: *Calculus, Analytical Mechanics.*

Observatory Work by Dr. Laves and Mr. Wilson.—Practice with the Equatorial and with the Universal Instrument in the Student's Observatory. First term, 2 hour sessions on 4 evenings a week.

Public Lectures—A course of Public Lectures on astronomical and astrophysical topics will be given at the University by Professors Hale, Barnard, and Frost, and Dr. Laves.

Solar Physics by Professor Hale.—This course, which extends through four quarters, includes systematic observational work with the telescope and spectroscope, supplemented by constant reference to the literature of the subject. Visual and photographic study of the solar photosphere, spots and faculæ. Use of the photoheliograph. Prerequisite: *practical astronomy, advanced physics and laboratory practice spectrum analysis.*

Astronomical Spectroscopy by Professor Frost.—This is a general course on the applications of the spectroscope in astronomy, with practical work.

Astrophysical Research by Professors Hale and Frost.—Students qualified for research will be given opportunity for special investigations in astrophysics.

Observations of Mira (*o* **Ceti**) **1998-9**.—(Continued from No. 60, Page 586.) This remarkable orb, having equalled the magnitude of Alpha Ceti in the beginning of October, which was a greater increase than it had attained during any of the five previous maxima, then very slowly waned to the magnitude of Gamma Ceti, taking 17 days longer to lose than to acquire the difference between these two comparison stars. In its decline no fluctuating tendency to regain lost lustre was noticed except what may be attributable to atmospheric causes. As shown in the following data, the pace however was uneven, decline from 4th to 5th and from 7th to 8th being more rapid than the intervening variations. Having decreased to the size of Gamma Ceti on November 15th it was more than half a magnitude dimmer at the end of that month.

December 3. It was equal to Delta Ceti.
8. Half a magnitude less than Delta.
13. Equal to the 5th magnitude star Xi Piscium and has a similar tint.
19. Just discernible to the naked eye but slightly brighter than 69 Ceti.
26. Still brighter than 69, 70 and other adjacent stars of 6th magnitude.

January 2, 1899. Equal to 69 Ceti.
5. Less bright than 69 but brighter than 71 Ceti of 6.7 magnitude.
19. After two weeks of cloudy nights the variable was seen to be dimmer than 71.
29. Equal to an adjacent star of 8th magnitude.

February 6. Midway between 8th and 9th magnitude.
18. No noticeable decrease.

March 4. This was the last observation that could be satisfactorily obtained. During the previous 26 days the variable seemed to be in a stationary stage. This is the first time in many years that the process of decrease has been observable down to 8.5 magnitude.

ROSE O'HALLORAN.

San Francisco, March 11, 1899.

Petitdidier's Optical Work.—I desire to announce to physicists, astronomers and others interested, that I am prepared to do all kinds of optical work of the highest grade. I have lately completed for the Ryerson Physical Laboratory, 200 plane parallel plates to be used in the construction of Michelson Echelson Spectroscopes in which the degree of accuracy required was that the plates should not differ from each other in optical thickness and parallelism by more than one-twentieth of a light wave.

O. L. PETITDIDIER.

149 FIFTY-SIXTH STREET, CHICAGO, ILL., U. S. A.

New Nebulae and Nebulous Stars.—Much care and skill are required to obtain the best results with the Bruce photographic telescope. Dr. De Lisle Stewart, who has had charge of this instrument for the last year, has succeeded in obtaining nearly circular images even when the exposures extended over several hours. He has recently found an interesting group of nebulae, hitherto unknown, within the limits of right ascension, $3^h\ 10^m$ to $3^h\ 50^m$ (1900), and declination, $-49°\ 50'$ to $-53°\ 40'$ (1900). A comparison of two plates, A 3339, and A 3346, taken on October 14 and October 20, 1898, respectively, with exposures of four hours each, shows the presence of the objects given in the following table. The current number assigned to each object is given in the first column, the ap-

No.	R. A. 1900. h m	Decl. 1900. ° ′	Description.
1	3 10.0	−50 58	2 faint elong. neb.
2	13.7	−51 1	Elong. n to s, small.
3	16.0	−49 57	Spiral?
4	16 7	−51 3	Elong. n to s.
5	17.2	−52 33	Double, elong. sp to nf.
6	19.4	−53 33	Elong. n to s.
7	21.4	−53 4	Stellar.
8	21.7	−51 5	Stellar.
9	21.7	−51 3	Stellar.
10	21.8	−50 55	Stellar.
11	22.1	−52 3	Elong. stellar.
12	22.3	−51 37	Elong. np to sf, stellar.
13	22.3	−52 3	Elong. stellar.
14	22.3	−52 5	Very faint.
15	22.5	−51 37	Elong. np to sf.
16	22.9	−51 41	Elong. n to s.
17	22 9	−51 8	Ellip. elong. sp to nf.
18	23.1	−50 22	Stellar, elong. spiral?
19	23.5	−51 40	Stellar, elong. np to sf.
20	24.4	−53 22	Perhaps double star.
21	24.8	−51 25	Elong. p to f.
22	24 8	−52 29	Neb. star.
23	25.2	−53 1	Stellar, elong. n to s.
24	26.5	−52 59	Stellar.
25	26.6	−52 58	Stellar.
26	27.6	−50 40	Stellar.
27	27.7	−50 39	Spiral?
28	27.7	−50 37	Star prec.
29	28.1	−50 46	Elong. np to sf.
30	28.3	−53 29	Elong. sp to nf.
31	28.6	−52 15	Fine small spiral.
32	29.4	−52 47	Elong. sp to nf.
33	29.9	−51 47	Stellar.
34	30.2	−50 45	Elong. np to sf.
35	30.9	−53 30	Elong. p to f.
36	31.2	−51 39	Stellar.
37	31.8	−50 58	Stellar.
38	33.2	−52 58	Elong. p to f.
39	33.6	−52 18	Elong.
40	33 6	−52 19	Elong.
41	33.7	−49 54	Elong. np to sf.
42	34.1	−50 29	Elong. n to s.
43	39.1	−51 17	Stellar.
44	41.9	−51 51	Stellar, elong. sp to nf.
45	42 3	−51 19	Stellar.
46	43.0	−51 58	Elong. n to s.

proximate right ascension and declination for 1900, in the second and third, and a brief description of the object in the fourth column. The letters n, s, p, and f, in the fourth column are used to indicate north, south, preceding, and following, respectively.

Only two nebulae are given, in this region, in Dreyer's New General Catalogue. N. G. C. 1311 is identical with No. 5, and N. G. C. 1356 is identical with No. 27.

It will be noticed that four of these nebulae appear to be spiral. No. 3 is described as "bright, elongated centre, faint nebulous wisps in ellipses or spiral." No. 18 "stellar nucleus with elliptical nebulosity sp." No. 27 "Faint Nebulous star surrounded by nebulosity. One wisp has spiral tendency. Two nebulous stars sp. and sf. very close to main nebulosity." No. 31, "Very fine small spiral nebula with two branches."

A bright meteor trail appears on Plate A 3346. EDWARD C. PICKERING.

January 31, 1899.